# Energy Conservation in Urban Areas in the Framework of a Sustainable Transportation Concept

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## Kurzfassung

Unsere Lebensqualität hängt in großem Maße vom Verkehr ab. Verkehr ermöglicht eine individuelle Freiheit und Unabhängigkeit für den Transport von Personen und Gütern in modern entwickelten Wirtschaftssystemen. Allerdings treten durch den Verkehr auch eine Vielzahl von unerwünschten Nebenwirkungen auf.

Der Verkehrssektor ist einer der größtem Energieverbraucher (hauptsächlich fossiler Brennstoffe). Die entstehen den Emissionen führen sowohl zu negativen lokalen Beeinträchtigungen der Gesundweit wie auch zu einer Erhöhung der CO2-Konzentrationen weltweit, die eine entscheidende Rolle für das Klima der Erde spielen. Zudem ist die Verkehrssektor weiterhin verantwortlich für eine Reihe gesellschaftlicher Probleme, wie beispielsweise Flächenverbrauch und Verkehrssicherheit.

Die steigende Motorisierung in einer bestehendem städtischen Infrastruktur ist heutzutage nicht nachhaltig. Petroleum Treibstoffe, von denen heute noch fast alle Verkehrssysteme abhängig sind, sind nicht erneuerbar. Zusammenfassend kann man daher sagen, dass das Verkehrssystem nicht nachhaltig ist und künftig noch weniger nachhaltig sein wird.

Es müssen daher Maßnahmen ergriffen werden, die zu einer Verringerung der negativen Effekte des Verkehrs führen und die versuchen, die Abhängigkeit von den fossilen Brennstoffen als Hauptenergiequelle zu reduzieren.

Die wesentlichen Ziele der vorliegenden Arbeit sind daher:

- Analyse des Energieverbrauchs des Verkehrssektors und den daraus entstehenden Problemen.
- Analyse der Nachhaltigkeit bestehender Verkehrssysteme.
- Definition eines nachhaltigen Verkehrs im Stadtgebieten.
- Analyse alternativer städtebaulicher Planungsphilosophien.
- Erarbeitung eines Modells mit Maßnahmen für eine nachhaltige Entwicklung des Verkehrs und des Energieverbrauchs.
- Anwendung des entwickelten Modells auf die Stadt Alexandria in Ägypten.

Hierfür wurden für das Jahr 2015 vier unterschiedliche Szenarien entwickelt. Die Szenarien wurden untereinander sowie mit dem Prognosennullfall („business-as-usual“) verglichen.

Die für den Vergleich benötigten Daten wurden mit den folgenden Programmen berechnet:

- TraEnergy (eigene Entwicklung).
- Visum (PTV System Software und Consulting Gmbh Karlsruhe/Deutschland).
- Dynamis (Institut für Verkehrswesen, Eisenbahnbau und –betrieb, Universität Hannover/Deutschland).

Zusätzlich wurde das deutsch-schweizerische Emissionsmodell des „Handbuchs der Emissionsfaktoren des Straßenverkehrs 1999“ im Rahmen der Berechnungen berücksichtigt.

# ABSTRACT

Our quality of life depends on transport. Transportation offers the individual freedom and independence to move and facilitates trade towards a modern developed economy. However, its widespread is recognized as a major contributor to an extensive range of undesirable side effects, covering all stages, from production to use and disposal. The transport sector is one of the major consumers of energy mainly fossil fuels and therefore contributes adverse emissions with local direct health effects as well as a significant share of “greenhouse gases” (GHGs), which play a crucial role in determining the earth's climate. Moreover, transportation sector is implicated in causing some social problems such as intensive use of public space. Present growth in vehicle ownership and use in urban areas, is unsustainable. Petroleum fuels, on which it is the main energy source for the transport sector, are essentially non-renewable. In short, the transportation system is unsustainable and is becoming more unsustainable. Measures need to be taken at a number of levels to mitigate the negative effects of transport and to reduce the increasing dependence on the fossil fuels as a main transportation energy source. The main objectives of this study are: (a) analyzing the transportation’s role in the energy markets and its related environmental problems and defining the sustainable transport in urban areas, (b) analyzing alternative urban planning philosophies, (c) presenting a suggested procedure for sustainable development of urban transport and energy consumption, (d) identifying the potential impacts of this procedure by being applied to Alexandria city, as a case study. The identification is based on evaluating four different scenarios for the year 2015 which are compared to each other, as well as with a business-as usual scenario (DO-Nothing Solution). These scenarios are based on the proposed sustainable transport and energy systems started from (Do-Minimum Solution) until (Do-Maximum Solution). To facilitate the calculations, an interactive computer program called “TraEnergy” is developed in the framework of this study. In addition, two commercials software are used: (1) a computer-aided transport planning called “VISUM” established at the PTV System Software and Constructing Gmbh Karlsruhe-Germany, and (2) a computer-aided interactive system called “DYNAMIS” established at the Institute for Transportation, Railways Construction and Operation of Hannover University Hannover- Germany. Moreover and for the aim of assisting the developing countries to produce energy and emissions models, the German-Swiss emissions model “Handbuch der Emissionsfaktoren des Strassenverkehrs 1999” is studied, explained and examined. Also, a new approach was developed, within the framework of this study, “Push-down and Push-up” with the aim of sustainable energy consumption in the transport sector. Finally, the application illustrates the technical, environmental, and economical benefits of the sustainable transport concept.

## SCHLAGWORTE

Verkehr – Energie - Nachhaltig

Transport – Energy – Sustainable

# LIST OF CONTENTS

# CHAPTER 1
# INTRODUCTION

The transportation systems play a major role in the economic life of each country and in the daily lives of its citizens. The movement of people and goods increases significantly with the rapid economic growth in both developing and developed countries. The increase in mobility is generally considered to be a positive aspect. However, too much traffic on a given transport infrastructure influences directly the natural resources, the environment, the urban image, and the land use. It also leads to negative effects. These negative effects include (among others) congestion, accidents, noise, and air pollution. Furthermore, the transport sector is a major consumer of fossil fuels and therefore contributes a significant share of "greenhouse gases" (GHGs), which play a crucial role in determining the earth's climate.

Development that meets the growing mobility in the future is difficult. Petroleum fuels, on which it is the main energy source for the transport sector, are essentially non-renewable, and emissions rates of the mobile transportation modes is exceeding the assimilative capacity of the environment.

Improvements in pollution control and fuel efficiency during the past three decades have been directed towards reducing the impacts of transportation on environment and health. The improvements have mostly been more than offset by increases in the ownership, the use, and the power of motor vehicles. The number of motorized road vehicles is growing almost everywhere at higher rates than both human population and growth domestic production (GDP). Movement of people by rail and bus, which is generally more environmentally benign, is declining in many countries. In short, transportation is unsustainable and is becoming more unsustainable.

Thus, the main objectives of this thesis are: (1) describing the “transport-energy-environment” problem and defining the sustainable transport in urban areas, (2) analyzing different planning concepts and presenting a suggested procedure for sustainable development of urban transport and energy consumption, and (3) investigating the technical, environmental and economical benefits of the proposed planning philosophy.

The dissertation consists of eight chapters which can be summarized as follows:

Chapter one introduces the subject and the objectives of this study as well as the research approach.

Chapter two is to analyze the transportation’s role in the energy markets and its related environmental problems in both developing and developed countries, as well as to examine the sustainability of the present transport systems.

Chapter three analyzes alternatives urban planning philosophies and presents a suggested procedure for sustainable development of urban transport.

Chapter four presents a suggested procedure for energy planning in the transport sector as well as to examine the concept of sustainable development energy consumption.

Chapter five is devoted to present and analyze the travel behavior, urban structure and transportation situation in Alexandria, as a case study.

Chapter six illustrates and calculates the transport energy consumption and emissions in Alexandria and develops a comparison between Alexandria city, Egypt, and Hannover city, Germany, for the aim of transferring technologies, knowledge and experiences.

Chapter seven presents a new transportation master plan for Alexandria based on the sustainable development concept of mobility and energy consumption and evaluates five scenarios for the future transport system in Alexandria, based on the different planning concepts, and investigates their sustainability.

Finally, Chapter eight highlights the overall conclusions and recommendations.

# CHAPTER 2
# THE "TRANSPORT - ENERGY – ENVIRONMENT" PROBLEM

## 2.1 General

In recent years, the principal international energy issues have gradually shifted from supply interruptions and their implications for energy security and price stability to the impacts of the energy production and consumption on the environment [1]. When the prime source of energy is fossil fuels, the energy consumption contributes adverse emissions of air pollution into the atmosphere. The negative effects of these emissions range from local direct health effects to global warming problems.

The transport sector is one of the major consumers of energy mainly fossil fuels. Over many decades, the demand for transport of people and goods have grown at a steady pace as a result of the expansion and development of the economy in general and the improvement of standard of living in particular. The aim of this chapter is to analyze the transportation's role in the energy markets and its related environmental problems in both developing and developed countries, as well as to examine the sustainability of the present transport systems.

## 2.2 Transportation and Energy

According to the published statistics, the total world prime energy production in the year 1997 was about 9653 Mil. ton oil equivalent (Mtoe). Between 1973 and 1997, the production increased by an annual growth rate of about 2.4 percent. Crude oil provided the largest share of energy supply, in 1997 about 36 percent of world primary energy supplies was oil.

The energy consumed by the transport sector was about 25 percent of the total final energy consumption in the world. This figure is quite different between the industrialized and developing countries. Transport within most developed countries accounts for about 22 percent of their total final energy consumption where in most developing countries this level is about 33 percent [2]. The reason of this may be related to the high energy consumption share for the industry sector in the developed countries as well as the high efficiency transportation systems in these countries.

Oil is the essential input energy to transport sector in both developed and developing countries. In 1997, the transport sector used more than 1577 Mtoe of the world petroleum products, 95 percent of the total transportation energy consumption (Figure 2.1).

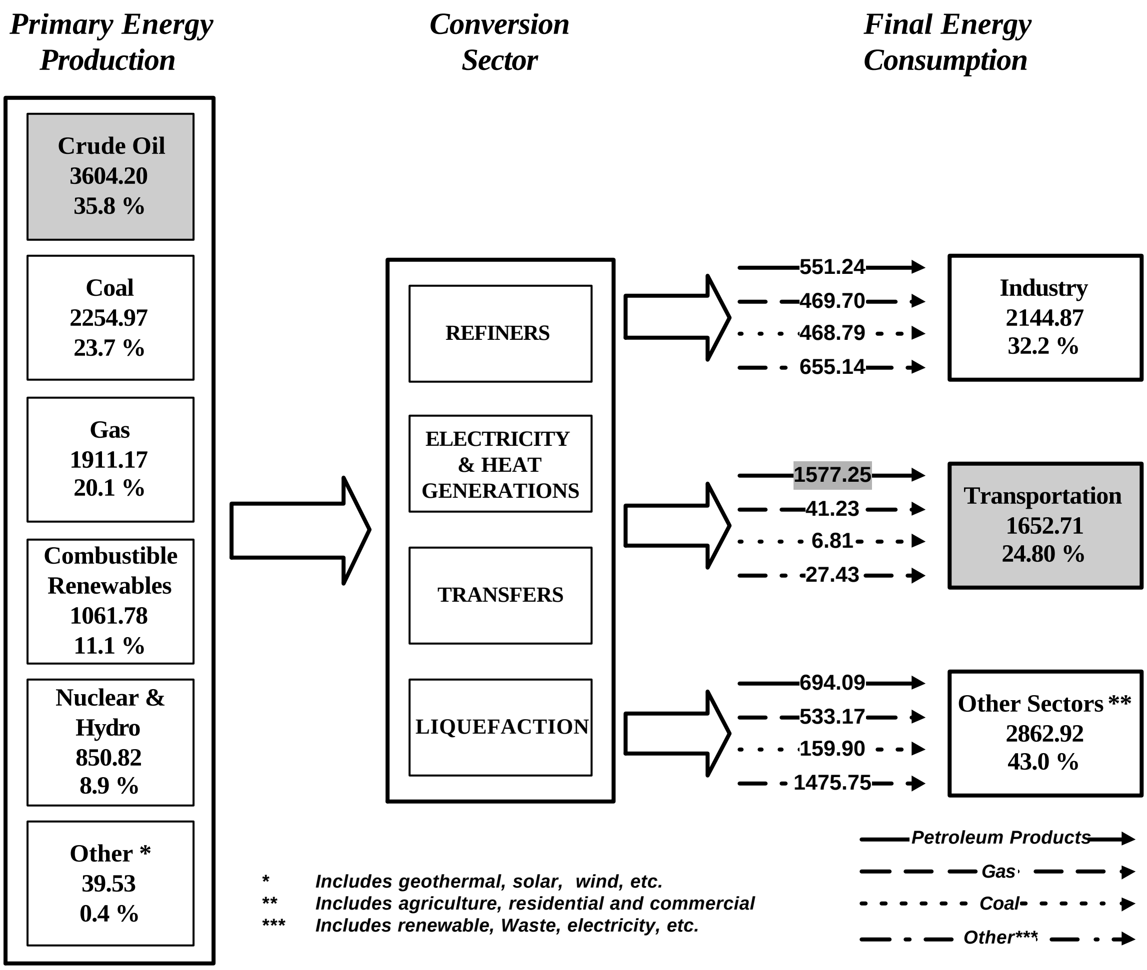
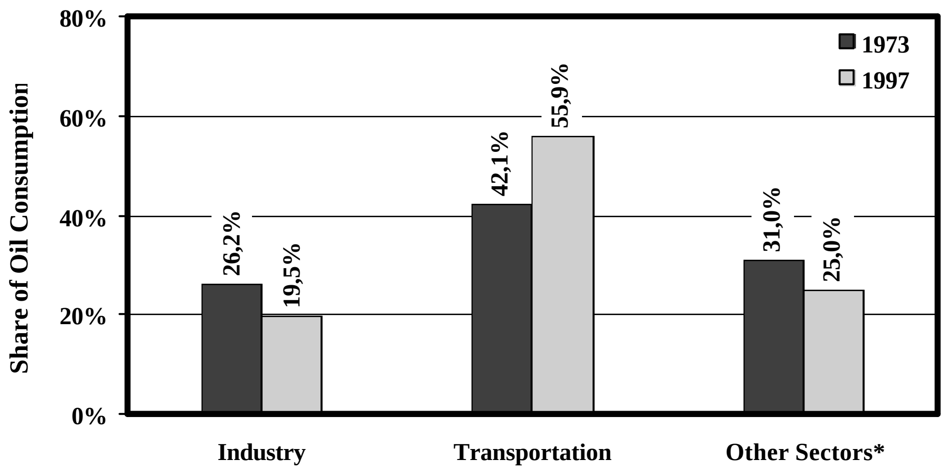



**Figure 2.1: World Energy Balance in Mtoe, 1997 (Data Source: [3])**

The transportation sector, 1997, comprised about 56 percent of the use of oil products (among the other economic sections). This level has risen in both absolute and relative terms over the past years. Between 1973 and 1997, the transport sector formed the only rapidly growing sector with petroleum products use at an average annual rate 3.1 percent.

The decline in the oil consumption, for other sectors, reflects primarily the trend toward switching to non-petroleum fuels particularly for electric utility, industrial boilers and power generation [4]. At current technologies, oil replacement possibilities are much easier and less expensive in both industry and residential sectors than in transport sector [4]. Figure 2.2 shows the different economic sectors share of the oil consumption in 1973 and 1997.




* Includes agriculture, residential, and commercial

**Figure 2.2: Share of Oil Consumption in the Different Economic Sectors, World 1973 - 1997 (Data Source: [3])**

In addition, most developing countries have increased their demand for energy as a result of the economic growth and high personal incomes. The growth in transportation oil demand within the industrialized countries averaged only 2.2 percent per year between 1973 and 1997, where in developing countries this rate was about 7.8 percent (more than three times the increasing rate in the developed countries). Table 2.1 presents the transportation oil consumption in both developing and developed countries as well as the total oil consumption.

**Table 2.1: Transportation Oil Consumption, 1973 - 1997**

| Year | Developing Countries | | Developed Countries | | Total World | |
|---|---|---|---|---|---|---|
| | Transportation | Total | Transportation | Total | Transportation | Total |
| **Oil Consumption (Mtoe)** | | | | | | |
| **1973** | 153 | 529 | 747 | 1609 | 900 | 2138 |
| **1997** | 442 | 962 | 1135 | 1861 | 1577 | 2823 |
| **Annual Growth in Oil Consumption (Percent per Year)** | | | | | | |
| **1973-97** | 7.80 | 2.30 | 2.20 | 0.65 | 3.10 | 1.30 |

Data Source: [5]

Thus, the transport sector can influence the fluctuations in the oil prices and the disruption of world oil reserves. Hereby, it should be noted that oil is a non-renewable resource, and the end of the oil production is in sight. Oil is being used at a rate 100,000 times faster than they are being formed [6]. According to best estimates, there is currently 143,000 Mil. ton of recoverable oil left on earth, enough to continue about 41 years at present consumption rates (Table 2.2).

**Table 2.2: Review of World Energy, 1999**

| Fuel Type | Crude Oil | | | |
|---|---|---|---|---|
| | Production (P) | Consumption | Proved Reserves (R) | R/P Ratio |
| **North America** | 19.0 % | 30.1 % | 8.0 % | 18.1 |
| **S. & Cent. America** | 9.7 % | 6.4 % | 8.5 % | 37.4 |
| **Europe** | 9.3 % | 22.4 % | 2.0 % | 8.4 |
| **Former Soviet Union** | 10.3 % | 5.4 % | 6.3 % | 24.8 |
| **Middle East** | 31.1 % | 6.0 % | 64 % | 38.2 |
| **Africa** | 10.2 % | 3.3 % | 7.0 % | 28 |
| **Asia & Australia** | 10.4 % | 26.4 % | 4.2 % | 15.9 |
| **Total World** | 100 %<br>3518.9 M. Ton | 100 %<br>3226.9 M. Ton | 100 %<br>$143*10^3$ M. Ton | 41 |

Data Source: [6]

Petroleum supplies the vehicles in the forms of gasoline, diesel fuel, liquefied petroleum gas, jet fuel, and residual fuel oil. Patterns of fuel consumption in the transportation sector vary widely from country to country. For instance, in the United States, gasoline is the dominant petroleum product used to fuel the vehicle fleet, whereas in France, Germany and other European nations, where gasoline is heavily taxed, diesel fuel use predominates [7].

In most developing countries, diesel fuel use dominates transportation energy use, but this is attributed to a high reliance on freight travel rather than a penetration of diesel-fueled passenger cars [2]. Worldwide, gasoline is considered as the largest fuel consumed by the transport sector in the world. In 1997, more than 52 percent of world petroleum products supplied to transportation was gasoline, 32.5 percent was diesel and 12.7 percent was jet fuel (Figure 2.3).

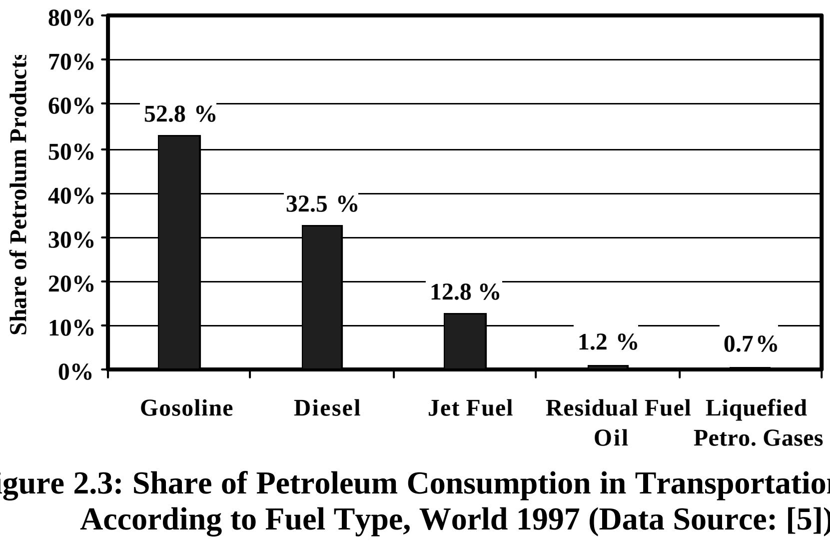



**Figure 2.3: Share of Petroleum Consumption in Transportation Sector According to Fuel Type, World 1997 (Data Source: [5])**

Road transport maintains a dominant share of transportation energy use. In 1997, road transport is responsible for about 79 percent of total transportation energy consumption (about 82 percent of total transportation petroleum consumption), whereas air, rail, navigation and pipeline respectively accounted for 13 percent, 3 percent, 2.5 percent and 2.5 percent. Table 2.3 illustrates the distribution of energy consumption according to energy type and transport modes in 1997.

**Table 2.3: Distribution of Energy Consumption according to Energy Type and Transport Modes in Mtoe, World 1997**

| Transport Mode | Petroleum Products | Gas | Coal | Electricity | Total |
|---|---|---|---|---|---|
| **Roads** | 1296.24 | 1.84 | 0 | 0.08 | 1298.16 |
| **Railways** | 30.94 | 0 | 6.52 | 13.65 | 51.11 |
| **Civil Aviation** | 204.64 | 0 | 0 | 0.02 | 204.66 |
| **Pipe line** | 0.34 | 39.16 | 0 | 2.38 | 41.89 |
| **Navigation** | 39.65 | 0 | 0.15 | 0 | 39.80 |
| **Non-specified Transport** | 5.43 | 0.23 | 0.14 | 2.99 | 8.79 |
| **Total** | 1577.24 | 41.23 | 6.81 | 19.12 | 1644.41 |

Data Source: [5]

Clearly, the growth in road energy use is strongly influenced by the growth in motor vehicle populations. Car ownership is expected to increase in the world as a result of population growth, increased in urbanization, and improving the standard of living and rising incomes. The high rate of this increase is expected to come, in the next years, from those countries that are currently developing rabidly or that have economics in transition (e.g. China, India) [8]. Table 2.4 presents the Worldwide vehicle ownership in 1980 and 1990 as well as the percent change. It shows that the rate of increase in vehicle ownership in Asia and Africa is greater than in other places.

**Table 2.4: Worldwide Vehicle Ownership Trends (Vehicles per 1000 Inhabitants)**

| Year | 1980 | 1990 | Percent Change |
|---|---|---|---|
| **Africa** | 13 | 21 | 61.5 |
| **Asia** | 19 | 33 | 73.7 |
| **South America** | 67 | 83 | 23.9 |
| **North America** | 588 | 769 | 30.8 |
| **Europe** | 217 | 278 | 28.0 |
| **Total** | **904** | **1184** | **31.0** |

Data Source: [8]

## 2.3 Transportation and Environment

### 2.3.1 Air Pollution

Air pollution can be defined as any natural atmospheric component which adversely affects human health or public welfare [9]. The effects of air pollution cover the whole range of spatial sizes, from local to global. On the local scale (single streets, urban areas, railway stations, etc.) pollution affects public health and the quality of life. Regionally, pollution affects plants and the built environment, through the dispersion, deposition and chemical transformation of the pollutants (photochemical reactions and acid rain). Globally, pollution is related to climate changes and the depletion of the stratospheric ozone layer. Table 2.5 schematically presents the extent of the various pollutant effects.

**Table 2.5: Impacts of the Transportation Sector Related Air Pollutants**

| Pollutant | Impact Type | | | | | |
|---|---|---|---|---|---|---|
| | Local | Regional | | Global | | |
| | High Concentration | Acidification | Photochemical Oxidants | Indirect Greenhouse Effect | Direct Greenhouse Effect | Stratospheric Ozone depletion |
| **Suspended Particulate Matter** | | | | | | |
| **Lead (Pb)** | | | | | | |
| **Carbon Monoxide (CO)** | | | | | | |
| **Nitrogen Oxides ($NO_x$)** | | | | | | |
| **Volatile Organic Compounds** | | | | | | |
| **Tropospheric Ozone ($O_3$)** | | | | | | |
| **Methane ($CH_4$)** | | | | | | |
| **Carbon Dioxide ($CO_2$)** | | | | | | |
| **Nitrous Oxide ($N_2O$)** | | | | | | |
| **Chlorofluorocarbons (CFCs)** | | | | | | |

Source: [9]

Fuel combustion is the largest single contributor to air pollutant emissions. Stationary and mobile sources (internal combustion engines) are responsible for approximately equal overall shares, varying significantly, for individual pollutants. Stationary sources refer to human activity sectors such as industry, agriculture, energy, etc., whereas mobile sources refer to transport activities such as motor vehicles, aircraft, ships, railways, etc.

Air pollutants caused by transport sector include both pollutants directly emitted by the use of vehicles (such as CO, $NO_x$, and HC), and secondary pollutants formed by chemical reactions in the atmosphere (such as photochemical oxidants). Pollutants commonly involved are the following:

- *Carbon Monoxide (CO)*, results from incomplete combustion, is an odorless and almost colorless gas. It interferes with the absorption of oxygen by hemoglobin (red blood cells) producing carboxyl-hemoglobin and thus restricting the supply of oxygen by the blood to body tissue. Carbon monoxide in urban atmospheres has been linked to loss of worker productivity and general discomfort. It affects the central nervous system, impairing physical co-ordination, vision and judgment.

- *Nitrogen Oxide ($NO_x$)*, forms by the combustion of fossil fuels particularly diesel, has a variety of direct and indirect effects on human health and public welfare. Nitrogen Dioxide ($NO_2$) is of great concern with respect to human health, acute exposure to $NO_2$ decreases gaseous exchanges in blood and increases respiratory symptoms producing lower lung-function values. These effects can cause irritation and eventually lead to oedema. $NO_x$ emissions are an important precursor to acid rain that may affect both terrestrial and aquatic ecosystems. This effect is even more pronounced when nitrogen dioxide and sulfur dioxide ($SO_x$) occurs simultaneously. Together with $SO_x$ they participate in the formation of atmospheric acids and therefore contribute for a large part to acid deposition.
- *Lead (PB)*, results from fuel lead which is added to attain the desired octane rating in gasoline, has long been known to damage the kidneys, liver, reproductive system, blood formation, basic cellular processes, and brain function at relatively high levels in humans. Lead enters the body primarily by absorption of ingested lead from the gastrointestinal tract and by absorption of inhaled lead from the lower respiratory tract. Studies have been carried out to quantify the effects of gasoline lead on human health, particularly on that of children. It has been found that both average blood lead levels and cases of lead poisoning in children correlate strongly to gasoline lead. Because of this close relationship, reducing the lead content of gasoline has been demonstrated to reduce significantly the health risks in urban areas.
- *Sulfur Dioxide ($SO_2$)*, results from combustion of fossil fuels particularly oil and coal which contain sulfur compounds, has a strong irritant to eyes and mucous membranes. With particulate it can form sulfuric acid ($H_2SO_4$) in lungs or as the main constituent in acid rain.
- *Volatile Organic Compounds (VOC) including the entire class of Hydrocarbons (HC)*, found in exhaust emissions or arise from spills and leaks of liquid or gaseous fuel, have long been considered traditional air pollutants because of the role they play in photochemical oxidant formation. Low-molecular-weight hydrocarbons are relatively non-toxic, but at relatively high concentrations, can cause unpleasant effects, which may include eye irritation, coughing and sneezing, drowsiness and symptoms akin to drunkenness. On the other hand, heavy molecular weight HCs cause more serious risks to human health even at relatively low concentrations. Some studies showed that some organic compounds may have carcinogenic or mutagenic effects. Benzene, for instance, as a constituent of gasoline and automobile exhaust, is a known human carcinogen causing leukemia.
- *Fine Particulate Matters* consist of small solid or liquid particles of varied chemical composition suspended in the atmosphere. They may be toxic in themselves or may carry toxic (including carcinogenic) trace substances adsorbed to their surface. Because of their

small size, they remain suspended in the air for a long time and can penetrate deep into the respiratory system, irritating lung tissue and causing long-term disorders. In urban areas, a strong correlation has been established between suspended particulars and variations in infant mortality and total mortality rates. Diesel particulate emissions are extremely small and therefore of special concern because they are combined with toxic compounds with potential carcinogen.

Emissions from the transport sector represent a high share of the overall man-made emissions. In 1997, transport sector was responsible for about 85 percent of CO, 60 percent of NOx, 50 percent of Pb and 50 percent of HC emissions. Figure 2.4 shows the share of the individual pollutants from the transportation sector.

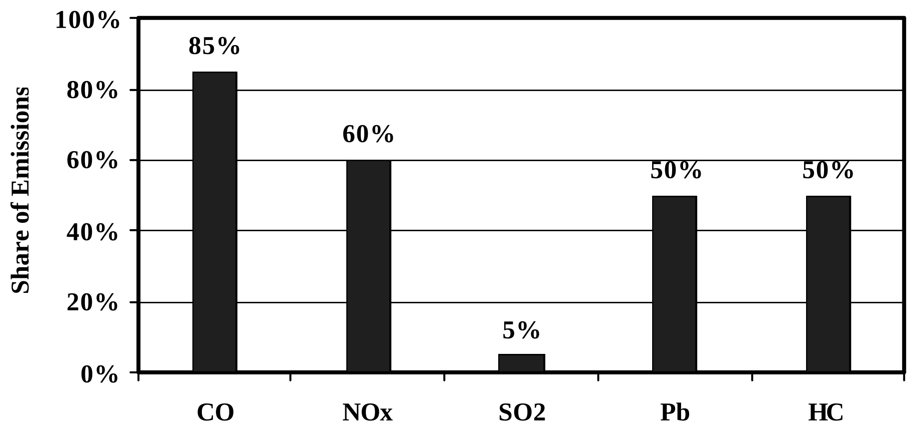



**Figure 2.4: Share of Emissions in Transportation Sector, World 1997 (Data Source: [10])**

Road transport is responsible for a large fraction of the air pollution around the world. In 1997, road transport accounted for more than three-quarters of the transport sector's contribution to global pollution [10].

The relative contribution from motor vehicles to deteriorating air quality in cities is higher than their shares on a national basis. In large city centers, road traffic may account for as much as 90 to 95 percent of lead and carbon monoxide, 60 to 70 percent of oxides of nitrogen and hydrocarbons and a major share of particulate matter [11]. These excesses are damaging to health, especially to pedestrians and those living or working in the open on traffic thoroughfares.

It should be noted that, while local conditions have improved recently in many developed countries, those in many developing-country cities have continued to decline. The air quality in the major cities of developing countries is already as bad or worse than that in cities in developed countries

(Table 2.6). Environmental studies show that air pollution in developing countries accounts for tens of thousands of excess deaths and billions of dollars in medical costs [12].

In Mexico City, it is estimated that high particulate levels contribute to 12,500 deaths per year [13]. Lead concentrations in some areas of Cairo are five to six times higher than the global norms of the World Health Organization (WHO), which results in the lead content in the blood of children in Cairo being three to five times higher than that of children in rural Egypt [13].

**Table 2.6: Ambient Air Quality Indicators for Some Cities, Av. Mean Concentration 1987-90**

| City/Emission | Pb | CO | $NO_2$ |
|---|---|---|---|
| Bangkok | ⊗ | ○ | ○ |
| Cairo | ● | ⊗ | NA |
| Jakarta | ⊗ | ⊗ | ○ |
| Berlin | ○ | ⊗ | ○ |
| London | ○ | ⊗ | ○ |
| Los Angeles | ○ | ⊗ | ⊗ |
| Mexico City | ⊗ | ● | ⊗ |
| Moscow | ○ | ⊗ | ⊗ |
| New York | ○ | ⊗ | ○ |
| Sao Paulo | ⊗ | ⊗ | ⊗ |
| Seoul | ○ | ○ | ○ |
| Tokyo | NA | ○ | ○ |

● WHO guidelines exceeded by more than a factor of two
⊗ WHO guidelines exceeded by a factor of up to two
○ WHO guidelines normally met
NA Not Available
Source: [13]

### 2.3.2 Greenhouse Gas Emissions (GHGs) and Climate Change

Global impacts of air pollution are the "greenhouse effect", caused by certain gases and possibly affecting the world's climate, and damage to the stratospheric "ozone layer", potentially a health hazard. The Earth's atmosphere has been transformed slowly, as human activity has pumped into it billions of tons of greenhouse gases (GHGs) such as carbon dioxide and large amounts of other gases that absorb the heat energy emitted from Earth's surface.

The principal force driving Earth's weather and climate change comes from the Sun. Although the Earth receives only about one two-billionth of the energy emitted by the Sun, this energy is enough to heat the Earth, drive ocean currents, and create weather patterns. The heat output of the Sun has varied by about one-third since life on Earth began, and continues to vary during the solar cycles. Despite this change, global temperatures have remained in a narrow range suitable for life [8].

During the past decade or so, people have become concerned with how human activity may be affecting the world's climate. This concern has focused largely on GHGs which generate by human activity such as the combustion of fuel for transportation. GHGs intensify the natural greenhouse effect because they absorb infrared radiation emitted from the Earth's, increase clouds and rein all directions [8]. GHGs occur naturally in the atmosphere, and they are essential to life on Earth in its present form. The concern is that human activity may be increasing the concentration of atmospheric GHGs enough to alter the climate.

Figure 2.5 illustrates the phenomena of the global warming creation, prevent and adaptation. The enhanced use of best available technologies, such as new vehicle technology, alternative fuels, and environmental transportation planning could help to prevent the climate change through reducing the use of fossil fuels and GHG emissions. In addition, the adaptation of particularly endangered infrastructures, such as avoiding construct the roads in the eroding places, could also help to protect our habitats from the possible effects of climate change.

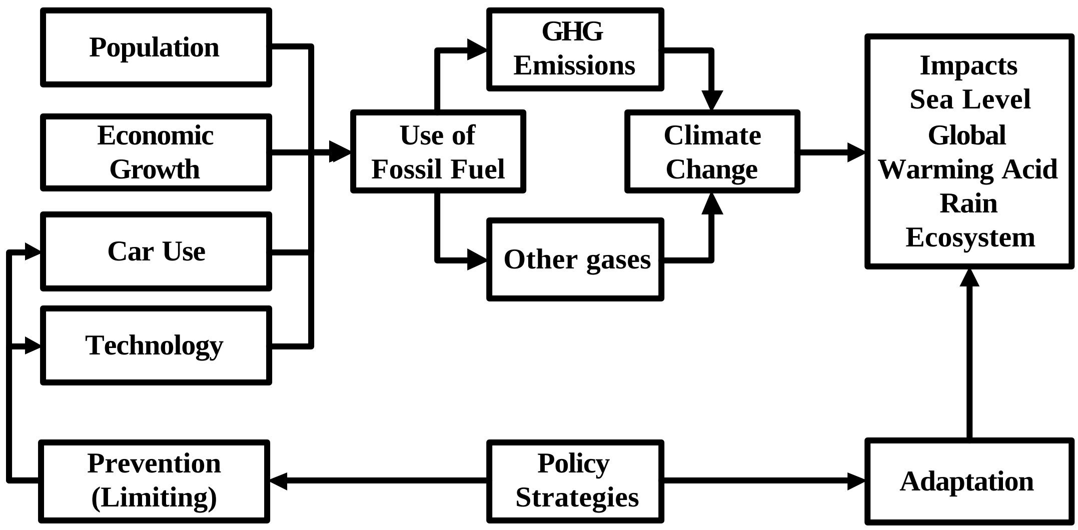



**Figure 2.5: Overview of the Global Warming Problem**

The gas primarily responsible for the greenhouse effect is believed to be carbon dioxide ($CO_2$). Global $CO_2$ levels are known to have increased since the industrial revolution. One reason for the increase is believed to be deforestation; there has been a decrease in the amount of vegetation which can absorb naturally or artificially generated $CO_2$. Another reason is the increased burning of fossil fuels. Figure 2.6 shows the role of the transportation sector as a source of carbon dioxide emissions from energy use.

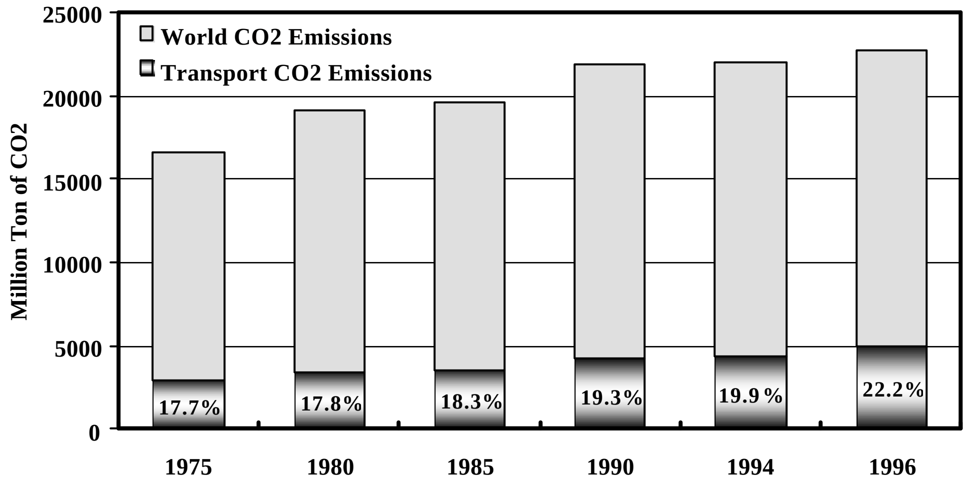



**Figure 2.6: World $CO_2$ Emissions Total and Transport Sector, [14]**

The other prevalent GHGs emitted from the mobile sources are the nitrous oxide ($N_2O$), and methane ($CH_4$). Some minor atmospheric constituents, such as the nitrogen oxides ($NO_x$) and carbon monoxide (CO), although not important GHGs in their own right, can influence the concentration of the GHGs through atmospheric chemistry.

If the fuels (mostly composed of hydrocarbons) are completely combusted, the only products emitted are $CO_2$ and water. However, under actual conditions, not all the fuel is combusted completely. As one example of combustion-related emissions, the motors release large portions of $N_2O$ emissions. These emissions are closely related to air-fuel mixes and combustion temperatures.

$CH_4$ emissions from the motors are a function of the methane content of the fuel, the amount of hydrocarbons passing unburnt through the engine. The emissions of unburned $CH_4$ are lowest when the quantity of hydrogen, carbon, and oxygen are present in exactly the right combination for complete combustion. Thus, $CH_4$ emissions will be determined by the air-fuel ratio. They are generally highest in low speed and engine idle conditions.

## 2.4 Sustainable Transport

### 2.4.1 Definitions

Since the l960s, there has been increasing worry over the human being impacts on the environment [15]. Many environmental topics have gained enlarged attention, such as population growth global warming and depletion of the ozone layer.

The 1972 United Nations conference on the Human Environment (Only One Earth), held in Stockholm, was the culmination of the first main signal of environmentalism.

In 1987 the “World Commission on Environment and Development” report, (Our Common Future), developed the notion of “Sustainable Development”, which has at present become a major feature of environment discussion [16]. Sustainable development has come to represent a way of living without making deterioration in environmental quality. Sustainability covers all sectors of society, including transportation.

Sustainable transportation is the expression of sustainable development within transportation. Sustainable transport is defined as the transportation that meets the needs of the present without compromising the ability of the future generations to meet their own needs [17]. The challenge is to discover ways of meeting mobility needs which are environmentally sound, socially equitable and economically viable.

The 1992 United Nations Conference on “Environment and Development” (UNECD), held in Rio de Janeiro, ensured that sustainable development was recognized by all nations [18]. The results of the conference were agreements on the Declaration and Agenda 21. In Agenda 21, a program for the realization of the principles enunciated in the Declaration was contained. The most important matter is the application of sustainability to broad range of the different economic sectors.

In Agenda 21, Chapter 7 covers the promotion of sustainable energy and transport systems in human settlements, with the purposes: “…extend the provision of more energy efficient technical and alternative/renewable energy for human settlements and, to reduce the negative impacts of energy production and use on human health and the environment”. It includes also the organization of resources for the transport sector. The basis of action is summarized as follows: “The transport sector has an essential and positive role to play in the economic and social development, and the transportation demands will undoubtedly increase. However, since the transport sector is a source of atmosphere emissions, there is a need for a review of existing transportation systems, and for selecting the most effective design and management of traffic and transportation systems”. The main objective was to develop and promote cost-effective policies for the transport sector which limit, reduce and control harmful emissions and other adverse environmental effects of the transport sector.

The final declaration of the United Nations Conference on Human Settlements “HABITAT II”, which was held in Istanbul in 1996, comprises the following sustainable transport strategies [19]:

(a) Integrate land-use and transportation planning to support development patterns that reduce transport demand,

(b) Adopt urban transportation plans favoring high occupancy public transport,

(c) Encourage non-motorized modes of transport by providing safe cycle ways and footways in urban and suburban centers in countries,

(d) Devote particular attention to effective traffic management and maintenance of transport infrastructure,

(e) Encourage the exchange of information among countries and representatives of local and urban areas, and

(f) Re-evaluate the current use and production patterns to decrease the use of energy and national resources.

In December 1997, leaders of the world's governments met in Kyoto, Japan, to discuss for the first time a protocol for reducing greenhouse gas emissions. Under Kyoto Protocol, nations must reduce their GHGs emissions (from fossil fuels), particularly carbon emissions, in the 2008 and 2012 by 7 percent for the United States, by 8 percent for the European Union, and by 6 percent for each of Japan and Canada, than those in the year 1990 [20].

Each country can apply abatement policies which adapt programs fitting their specific local conditions. For example, the European Commission proposed to adopt the following exhaust emission limits for cars to become effective in years 2000 and 2005 (Table 2.7).

**Table 2.7: Mandatory Passenger Car Emissions standards (g/km) in European**

| **Name** | **Euro III** | **Euro IV** |
|---|---|---|
| **Year of Introduction** | **2000** | **2005** |
| **Gasoline -fueled (g/km)** | | |
| **CO** | 2.30 | 1.00 |
| **HC** | 0.20 | 0.10 |
| **$NO_x$** | 0.15 | 0.08 |
| **Diesel-fueled (g/km)** | | |
| **CO** | 0.64 | 0.50 |
| **HC** | 0.56 | 0.30 |
| **$NO_x$** | 0.50 | 0.25 |

Data Source: [21]

It should be noted that the United States, the world's leading emitter of greenhouse gases, has refused to work with the Kyoto protocol. The White House made it clear on that any future negotiations on global warming will have to take place under a framework other than that agreed in the 1997 Kyoto treaty. Washington objects to the exclusion of developing nations from strictures on limiting greenhouse gas emissions - and says the US economy cannot afford the emission cuts imposed under Kyoto.

U.S.A President George W. Bush on March 2001 justified his opposition to an international global warming treaty by saying “I oppose the Kyoto Protocol because it exempts 80 percent of the world,.……..and would cause serious harm to the U.S. economy. The Senate’s vote shows that there is a clear consensus that the Kyoto Protocol is an unfair and ineffective means of addressing global climate change concerns”.

The European environment commissioner declared, "Without the participation of the world's biggest polluter, the Kyoto protocol is in serious trouble…… We are ready to discuss details and problems the US has with Kyoto but not to scrap it, because that would mean the end of climate talks”. The question now, what will be the fate of the Kyoto protocol and the climate protection?

### 2.4.2 Unsustainability of Present Transport System

The impact of modern development on the environment has long been a cause of concern at national and global levels. The rate and scale of the trends in environmental degradation, however, have been growing significantly with the improving of the standards of living. Growing environmental awareness has led to the belief that infinite growth within a finite system is unsustainable, and that the natural limits should be appreciated [22].

As a result of the expansion and development of the economy in general and the improvement of standard of living in particular, demand for transport of people and goods increases and consequentially energy consumption and pollutant emissions as well. Yet the increase in the quality of life, as a result of motorization, is starting to turn into the opposite direction; i.e. deteriorating living standards.

The problems of high level of motorization, inefficient use of scare fossil fuel resources, emission of harmful pollutants and deterioration of quality of life are linked to such an extent we can say the “transport - energy - environment” problem (Figure 2.7).

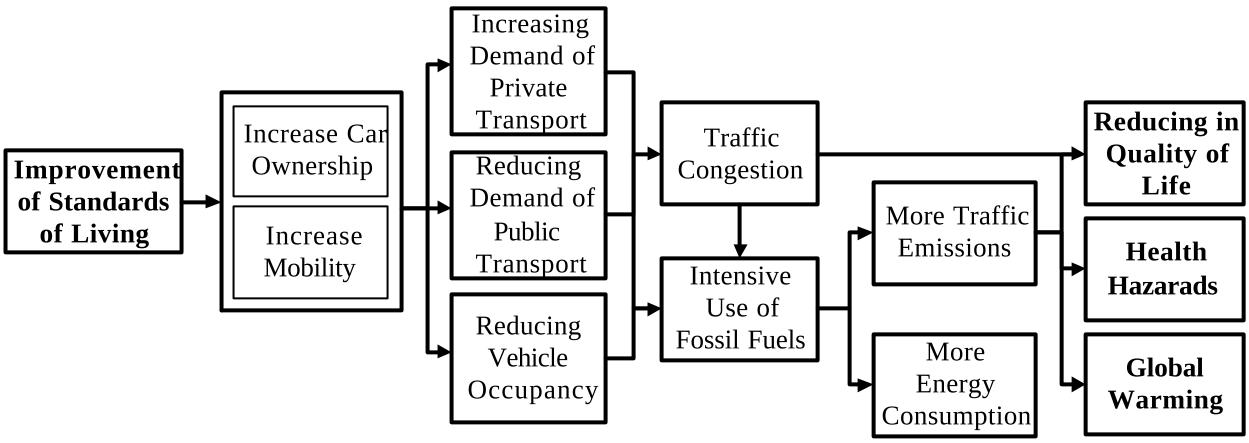



**Figure 2.7: The “Transport - Energy - Environment” problem**

# CHAPTER 3
# ENERGY CONSUMPTION IN THE FRAMEWORK OF SUSTAINABLE TRANSPORT SYSTEM

## 3.1 Introduction

As the concept of sustainable development becomes the guiding principle within the realm of human development, there is need to reduce and eliminate unsustainable patterns of human settlements. Transportation creates a substantial threat to the sustainable development, despite the efforts in the technical field.

While motor vehicles are getting cleaner and more energy efficient over time, growing transport volumes and use of heavier and more powerful vehicles offset these benefits. The OECD policy meeting on (*Sustainable Consumption and Individual Travel Behavior*), states that: “it has become clear that technical measures alone will not be sufficient to render transport systems more sustainable” [23].

In addition, in developing countries, rapid motorization and insufficient investments in urban-transport planning, traffic management and infrastructure are creating increasing problems in terms of accidents and injury, health, noise, and congestion [24]. All of these problems have severe negative impacts on the urbanity and the lifestyle of the citizens in these countries [24].

Therefore, there is need for an examination of existing transport systems and for more effective design and management of the transport systems. The basic objective of a sustainable transport concept is the development of promote cost-effective urban and transportation policies, as appropriate, (a) to satisfy the travel demand, (b) to save energy and (c) to control harmful emissions into the atmosphere as well as other adverse environmental effects of the transport sector, taking into account the needs for sustainable social and economical development [24].

This chapter provides a concept towards improving urban transportation and an account principle of strategic directions for its sustainability which, involves more than attainment of environmental criteria.

## 3.2 Alternatives Philosophies for Transportation Planning Concepts

Traditional approaches to transportation planning (called also "Demand-oriented Planning") are based on the notion of "predict demand and provide facilities", i.e. meeting the travel demand by providing extra traffic infrastructure [24].

Building more and more roads in the cities and conurbation, where possible, enables more people to travel by car, but not reduces peak-period congestion to any noticeable extent [26]. As soon as new roads space becomes available in large cities, it is quickly filled [24].

In the eighties, the increase in environmental awareness has highlighted the issue of transport as an important environmental problem. A wide consideration has been given to the transportation planning process to include noise and air pollution. The "Environment-oriented Transportation Planning" ensures minimum impact on the environment, by applying traffic calming measures, car use restrictions and parking control. Such anti-car techniques are used in a relatively piecemeal fashion up to now, so that cities still seem to be largely dominated by road traffic [24].

Figure 3.1 shows that the only way to prevent the deterioration of mobility development (mobility break-down) is not only by applying the "anti-car" measures to match the mobility with the road capacity (mobility break), but also through the sustainable transport (mobility jump) [27].

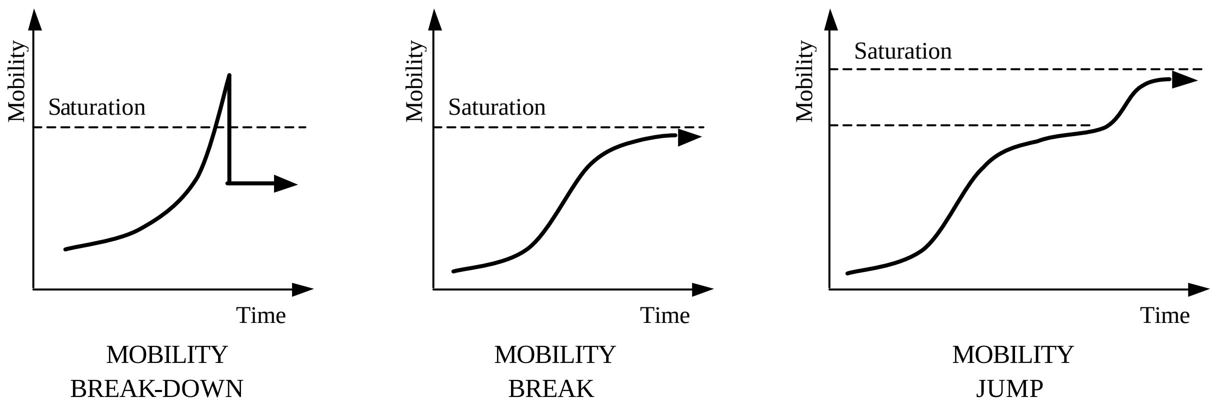



**Figure 3.1: Development of Mobility**

This means, the main effort is to change the transportation planning philosophy itself, from the traditional approach to sustainable transport; i.e. not to improve the environmental performance of an existing transport system, but to change the transport system itself with a view to the environmental constraints [24]. The goals are: (1) to make sure that all road users are taken into consideration in a sustainable way, and (2) to generate new human settlements along development axes in the framework of integrated land use/transportation planning [28]. This new philosophy is called "Sustainable-oriented Transportation Planning".

Figure 3.2 presents the concepts of the three transportation philosophies for mobility planning; i.e. Demand-oriented Transportation Planning, Environment-oriented Transportation Planning, and Sustainable-oriented Transportation Planning.

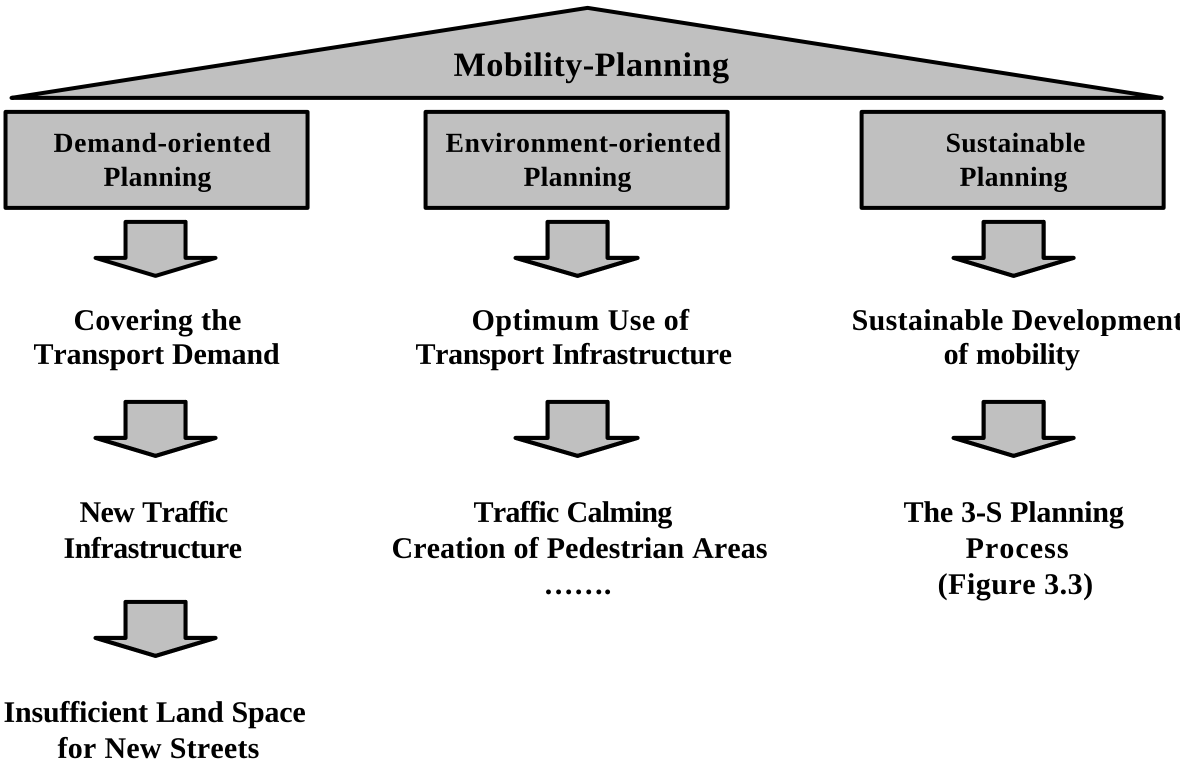



**Figure 3.2: Concepts of the 3 Philosophies of Mobility Planning [24]**

## 3.3 Sustainable Transportation Planning

In the town of the future, the transport model is based on the existing road network and its potential to accommodate a fast and reliable surface public transport system and to give more space to the pedestrians. Then, the car can get only the remaining area after the satisfaction of the higher priority road users (public transport passengers, and pedestrians). Thus, the main objective of the transportation model is to guarantee the traffic accessibility in an attractive and inexpensive way, and simultaneously the freedom and the safety of pedestrians.

There are three different strategies for the reorientation of the traditional transport model in the future (Figure 3.3): (1) saving motorized traffic “reducing travel demand”, (2) shifting motorized traffic "modal shift from less to more environmentally friendly transport modes", and (3) smoothing motorized traffic "environment-friendly flow of car traffic".

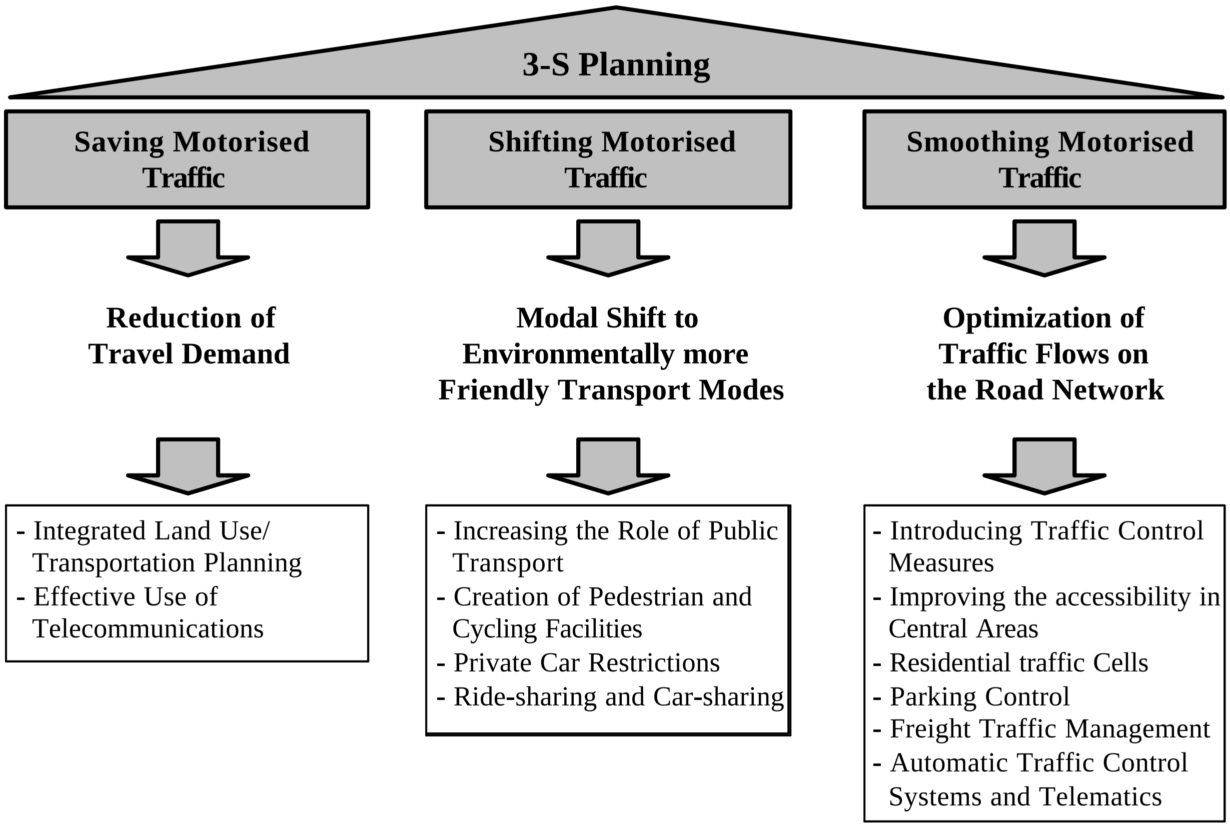



**Figure 3.3: The 3-S Planning Process**

### 3.3.1 Saving Motorized Traffic

Reducing travel demand strategies have the ability to reduce the need to travel, and promote preferred modes of travel. These strategies have major application in urban areas and can provide a range of complementary benefits in terms of improvements in energy consumption, emissions, and traffic congestion [29].

Integrated land use/transportation planning and the effective use of telecommunication systems may represent reliable opportunities for reducing travel demands through management.

#### 3.3.1.1 Integrated Land Use/Transportation Planning

The integration of urban land use and transportation planning offers significant long-term potential for reducing energy consumption and emissions through decrease the demand for travel both in terms shorter journeys and less frequent travel. Different land use configurations have important implications for travel demand, which consequently affect the environment (Figure 3.4).

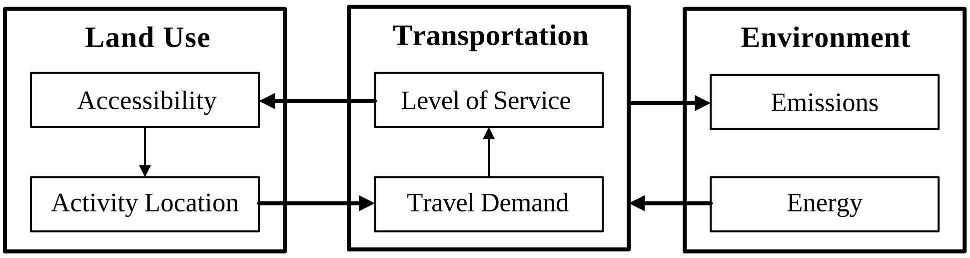



**Figure 3.4: Land Use, Transportation, and Environment Relationship**

Urban and regional development, determined partly by public policies, have induced urban spread and the concomitant spatial segregation of the different urban functions. To this aim, school, work, shopping and recreational facilities should not be centralized, but decentralized within the city quarters [30]. Short distances, accessibility and mixed and varied usage create pedestrian traffic and urbanity.

Land use planning can also enhance the use of public transport systems. This involves ensuring that trip-attracting activities are concentrated in locations that are easily accessible by public transport and targeting areas well-served by public transport for new residential, commercial and business developments [29]. Concentration of trip-attracting activities around railway, tram and bus stations, has been a positive effective in producing a modal shift from car to public transport in a number of cities, e.g. Hannover, Stockholm, and Vienna.

The need to coordinate land use in urban areas and transport decisions is especially acute in the main cities of most developing countries where simultaneous and almost uncontrolled population growth and motorization contribute to lengthy urban trips, congested traffic and a stress-producing living environment. In many cases development patterns remain highly centralized [31]. Development focuses around a city center that contains most of the local administration offices, financial houses, shops, wholesaling warehousing activities and sometimes a major port. Consequently the central area may attract 50 percent or more of the total daily trips [28].

#### 3.3.1.2 Effective Use of Telecommunications

With increasing penetration of telecommunications in individual homes and businesses, coupled with the widespread availability of computing equipment, there is renewed interest in exploring and encouraging telecommuting arrangements. These include work-at-home schemes and workplace decentralization with satellite work centers.

Telecommunications can also cause trips to be made at different times, perhaps avoiding peak periods. Telecommuters and other home workers with flexible schedules have more opportunity to do some necessary tasks during off-peak periods, and stay at home during the peak periods.

In 1992, a survey in the United States (where telecommuting is probably most highly) found that 4.2 Mil. employees, 3.3 percent of the workers, were telecommuting, a 27 percent increase from the previous year [32]. Projections developed by the US Department of Transportation (DOT) suggest that by 2010 there may be 30 Mil. telecommuters and the corresponding net fuel saving would amount 2 percent of total motor fuel use [32].

### 3.3.2 Shifting Motorized Traffic

The limited capacity of urban transport infrastructure to cope with growing traffic volumes and the ensuring crisis of the transport system itself call for modal shift. This is strongly connected with land use issue because short distances are a prerequisite for walking and cycling, and public transport is suitable for long distance trip. Modal shift can be approached through making the environmentally preferable modes more attractive (increasing the role of public transport and creation of pedestrian and cycle facilities) as well as discouraging the use of the less clean modes (private car restraint).

#### 3.3.2.1 Increasing the Role of Public Transport

*a) Improve and Upgrade the existing Public Transport Systems*

All policies are insufficient if not combined with an integral public transport system. Continually improve and upgrade the public transport systems are very important to cover the rapid increase in the transport demand and to encourage the pull-and-push approach.

The European Commission Council on the future perspectives of the (*Common Transport Policy-Action program 2000-2004*), states that: “An important challenge is to improve the quality of local public transport which is the only form of transport available to all citizens, particularly in large cities” [33]. This is especially evident in the developing countries where the public transport systems are in need of re-organization and renovation.

Criteria for the attraction of railway and public transport system are multiple. Certainly, their speed, comfort, reliability, schedule and network design are crucial factors. Permanent right-of-way for light railways, separate bus lanes, park-and-ride facilities, an extended night service and the improved image of the public transport are also items in a whole catalogue of possible actions [31].

Reducing fares through Government subsidies might also increase public transport patronage through lower comparative prices with private car. However, practical experience demonstrates that lower fares require additional government expenditure to maintain service levels and investment in the system.

In Germany, 1970, a special law was made for the goal "*Community Transportation Financing Law*". A fixed part of petrol tax (0.06 DM/l) was devoted for investment in infrastructure of public transport system. The result, between 1970-1995 (25 years), was 40 billion DM investments in the public transport systems [34].

*b) Introduction of new Regional-Urban Railway Systems*

The different forms of public transport are not equally successful in providing an attractive alternative to the car. Rail is usually regarded as superior to bus as it operates over protected rights of way and can accordingly achieve high line-haul speeds and good service reliability.

The primary benefit of urban railways is their much higher carrying capacity per track than that of most urban transport systems. Railways provide an alternative to congestion on the streets. If rail systems carry a large proportion of the traveling public, then the paved areas can be safer and less crowded. Streets can be restricted to pedestrians, cyclists, trams, buses, taxis and a limited number of priority category private vehicles. Thus an effective rapid transit system for city dwellers or workers can complement an improved environment.

The wide range of urban railways systems, with different characteristics of vehicle, track and method of operation, may be considered under four opportunities [35]:

1. Regional rail transit; trains which can be operated to link the towns with the suburbs.
2. Light rail transit; electric city trams (short trains) with moderate speeds, ranging from trams operating in mixed traffic along public streets to semi-metro rail system on partially exclusive tracks.
3. Metro rail transit; metro trains operate on completely exclusive rights-of-way at high speeds.
4. Regional-Urban Railways (RUR); shared track.

The concept of regional-urban railways can be applied either to allow light rail transit to expand into the suburbs, the countryside and to neighboring towns, or to bring conventional railways into city and town centers. The second application is a potentially exciting one, which could have considerable impact where inter-modality, would be of high value.

A significant breakthrough has been demonstrated in Germany. Karlsruhe city trams now operate over a main line railway. Traffic has vastly increased on the railway concerned, passenger have a more frequent and convenient service, but the most important change is that they now travel directly to shops and offices in the city center, not to station on the edge of the central area. Very little new infrastructure has been required in order to achieve this improvement. Today, the Karlsruhe system is being extended progressively with more shared track operation. This system has the major advantage of being highly efficient. This shows up clearly in the fact that about 40 percent of the passengers using the Karlsruhe RUR were car user before its operation and the net reduction in the energy consumption by the transport sector was about 20 percent [35].

*c) Traffic Priorities for Buses*

As congestion increases, buses become slower and less attractive. Bus-priority schemes enable buses to pass traffic queues and penetrate streets or zones that are denied to private traffic. In addition, they may be regarded to permit some other vehicle categories such as high occupancy vehicles and emergency service vehicles. Bus-priority measures vary in scale, from simple traffic management measures such as "With-flow Bus-Lanes" and "Contra-flow Bus-Lanes" to comprehensive traffic management such as "Comprehensive Area or Route-Based Schemes" where buses are provided priority over complete route or areas.

A with-flow bus lane is an area of carriageway reserved for the use of buses, for all or part of the day, in which the buses operate in the same direction as the general traffic flow. This scheme has been very effective in some North American cities in increasing bus use and car pooling [32].

A contra-flow bus-lane is a traffic lane reserved for the use of buses traveling in the direction opposed to the general traffic flow. It is usually introduced in one-way roads, where the effect is to create a two-way road with buses only allowed in one direction and all types of vehicles including buses in the other.

Enforcement of conventional bus lanes over complete route or areas is difficult. Combining physical traffic management measures, such as bus-lanes, with traffic control system, such as active bus-priority at signals, are most valuable when implemented along bus-route corridors. A bus-priority at signals is a traffic measure which permits buses to advance into an area of road, clear of traffic, before a signal-controlled junction. This system has proven successful in some Germany cities, e.g. Hannover, in reducing transit times and increasing the attractively of buses.

#### 3.3.2.2 Creation of Pedestrian and Cycling Facilities

Promoting walking and cycling can reduce the use of motorized transport in urban areas and thereby help to improve the environment. The tendency to walk and cycle is affected by four main factors:

1. Level of safety.
2. Degree of easy access to major attractions.
3. Quality of the walking and cycling environment.
4. Degree of preparation for the special needs of the young, elderly and people with disabilities.

In most urban areas, especially in developing countries, the needs of vehicular traffic have taken precedence over the needs of pedestrians and cycling [36]. Urban transportation plan should give more priority of walking and cycling by:

- Creating "car-free" zones in the shopping streets of the city center, as well as in other parts of the town, such as residential, recreation, and historical districts,
- Reassigning road space to pedestrians and cycling,
- Improving footpath maintenance and cleanliness,
- Providing more pedestrian and cycling crossings,
- Reducing waiting times for pedestrians and cycling at traffic signals and giving them priority in the allocation of time at junctions, and
- Introducing large-scale-traffic calming measures in residential zones and near schools.

A pedestrian-oriented town is not necessarily “anti-car”, even in “purely” pedestrian streets, it is generally possible to permit vehicular traffic to access. Pedestrian zones can be used by emergency service vehicles, public transport modes, and delivery vehicles. Moreover, cars and taxis may also be allowed to enter the inner restricted zone, if they are fully occupied.

Not infrequently, an inner-city pedestrian zone is surrounded by a "city wall" in the form of a fast ring road. Such an express ring road can isolate the pedestrian area. Sensible planning must avoid this sort of barriers. No "inner-city ring road" is recommended to be created. Division into different traffic systems, outer accessibility and inner circulation, is also a question which arises, especially when solutions are suggested. A danger appears if the layout is wrong. In this case, the through traffic finds his way in the city center. "Short Cuts" must be excluded. Vehicular circulation should be organized and controlled so that it does not suppress the safety of the pedestrians.

Many cities in Germany, e.g. Hannover, have successfully implemented pedestrian-oriented town. These typically consist of a set of radial pedestrian and bicycle streets while cars used a ring road around these areas. This scheme has verified successful in eliminating motorized traffic in central areas and shifting short automobile trips in the central area to walking, bicycling, and public transportation.

#### 3.3.2.3 Private Car Use Restrictions

The easiest way to deter people from private car is the charging of high pricing measures that aim to reduce car travel by increasing its cost, and the driver's awareness of the cost. The best known mechanisms of the pricing measures are: parking charges, road pricing, emission fees, and fuel taxes.

Free or discounted vehicle parking causes a strong incentive for vehicle trips. Charging of high parking fees would reduce the demand for private car travel in favor of alternatives. Parking pricing is often collected at the point of use and therefore it has an explicit linkage to the particular trip. Many studies have concluded that such an out-of-pocket cost has a greater impact on decision-making than costs that are averaged over a longer time period or multiple uses [36].

The concept of road pricing “or road taxation” as a transport planning tool is more recent and attracts more and more attentions. Travelers are charged for the number of trips they make and, in the case of congestion pricing, for the congestion cost that they impose on the transportation system. Singapore, Hong Kong, and Oslo are already following this path.

The Singapore Area Licensing Scheme (ALS) is the simplest form of congestion charging, with users incurring a fixed charge for entering an area during the charged period. The Singapore ALS has reduced by half the number of work trips into the city by car and average pollution concentrations by 10 percent [36].

Emissions fees vary in their impacts, depending on how they are designed. Most easily, a tax is added to the registration fee that reflects vehicular emissions. The fee is ordered to the type and manufacture’s year of the vehicle as an agent for contribution to emission. This approach would be expected to influence at least the distribution of a country's automobile fleet between more and less fuel consuming or "clean" cars. More targeted applications link emissions fees to variable costs incurred by the driver such as the petrol tax [37].

On April 1999, the law of "first step towards an ecological tax reform named ökologische steuerreform" came into effect in Germany. The term "ecological tax reform" is used to denote the introduction or increase of environmental taxes or charges (i.e. levy on environmentally harmful products or production processes). By increasing the price of these products, an incentive is created to ease the burden on the environment and to use natural resources more economically. The revenues are intended to promote technological and organizational innovation, which will increase the future "environmental efficiency" in production and consumption. For this aim, vehicle fuels prices increase annually by about 0.05 DM/liter. Furthermore, to encourage their use, renewable energy sources used by energy producers are exempt from the new tax [38].

Fuel tax is a powerful tool in influencing overall actual driven distance, and accordingly affecting traffic congestion and pollution. From an economic stand point of view, fuel taxes are often described as the most efficient means of reducing private car use and consumption of fuel [29]. However, it is thought that increasing fuel efficiency offset the effects of this increase in the fuel price. To be effective much greeter price increases would be required. The revenues can be invested to finance roads and highways maintenance.

#### 3.3.2.4 Ride-Sharing and Car-Sharing

Low vehicles occupancy and high levels of vehicle ownership have been mentioned as the main forces behind ride-sharing and car-sharing schemes.

Ride-sharing is an attempt to respond to the fact that for daily commuting from home to work most drivers are alone in their vehicle. The principle offers the scope to use a car with more occupant seats. It involves the use of one person's private car (car-pooling), company vehicle to carry more passengers (van-pooling), or collective taxi. This scheme is most effective in areas that are frequently accessed, such as universities, hospitals and the central business district.

Car-sharing, or car-time-sharing, gives city dwellers an alternative to ownership. The objective of such scheme is to reduce the number of cars encouraging people to spend less time driving and reducing demand for parking space. This concept has proven quite successful in Europe, mainly in Germany and Switzerland. The ownership of private cars is reduced, together with the demand for parking space forming one aspect of a range of environmental benefits arising from the scheme. Table 3.1 presents the real and potential car-sharing scheme in Germany as well as its benefits in terms of less car ownership, activity, fuel consumption and emissions [39].

**Table 3.1: Car-Sharing in Germany**

| Car-Sharing | Real (1994) | Potential (Target) |
|---|---|---|
| **No. of persons using Car-sharing (in 1000)** | 6 | 2450 |
| **Ownership Reduction (1000 Cars)** | 2.936 | 1199 |
| **Activity Reduction (Mil. km/year)** | 17.7 | 7227.5 |
| **Energy Reduction (Pj/year)** | 0.05 | 22.08 |
| **$CO_2$ Reduction (1000 t/year)** | 3.673 | 1500 |

Source: [39]

### 3.3.3 Smoothing Motorized Traffic

In spite of the wide increase of the economic, ideological and political interests in improving the urban environment, there is still much to be done. Until now, remodeling towns is usually carried out without adequate considerations of the miscellaneous urban requirements [39]. A new urban transportation scheme may involve introducing traffic control measures, improving the accessibility in central areas, residential traffic cells, parking control, freight traffic management, and introduction of intelligent transport systems.

#### 3.3.3.1 Introducing Traffic Control Measures

The introducing of traffic control measures can be determined through [24]:

- Re-classification and assignment of the roads on the network including outer ring, urban highways, main corridors, secondary roads, one-way-streets.
- Re-alignment of junctions based on the actual traffic volumes for reducing the number of conflict points and traffic delays.
- Introduction of integrated traffic signals that are operated according to the actual traffic volumes by using detectors.

#### 3.3.3.2 Improving the accessibility in Central Areas

To improve the accessibility in the central areas, these measure can be applied [24]:

- Creating car-free zones (pedestrian zones and streets) in the main shopping areas.
- Introducing area traffic control system
- Co-ordinated traffic signals in each central area are to be installed at all major intersections, for minimizing the delays and optimizing the traffic channelization.

#### 3.3.3.3 Residential Traffic Cells

For the interest of residents, traffic cells including large-scale- traffic calming measures with 30 km/h or 20 km/h speed limits are required. These measures includes, among others, one-way streets, loops, culs-de-sacs, road humps, raised junctions, bottlenecking, new layout of parking spaces, planting of trees, pedestrian-orientated signs and modern signal systems, such as the so-called the "crosswise crossing" which allows the pedestrian to cross diagonal on the shortest distance [40].

#### 3.3.3.4 Parking Control

Parking regulations measures can play an important role in reducing congestion, energy consumption and emissions [41]. The aim of the planning in the past (and till now in many cities in developing countries) intended to provide more parking places and duration around the pedestrian area and at the vehicular streets [42]. These measures always lead to negative impacts (Figure 3.5).

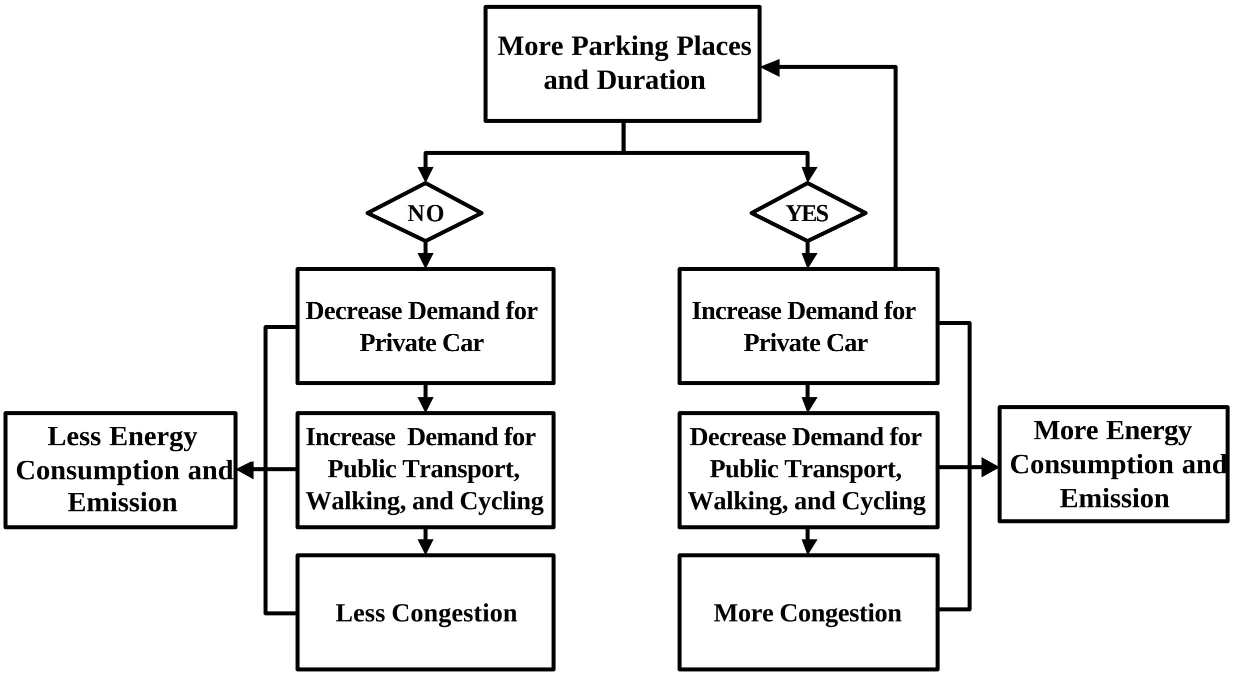



**Figure 3.5: Relationship between Parking, Congestion and Environment**

In order to improve the parking potential, long-term parking should be changed to short-term. Car park charges should be "progressively" structured [43]. The planners do not recommend, often, the short-time parking meters as a universal tool because they increase the amount of traffic through the city center.

Long-term parking places are to be transferred to the edges of the city (park-and-ride) at the terminals of regional railways and metros, and close to highway junctions [44]. One of the findings in German cities is the growing number of motorists who prefer to park their cars and ride the public transport systems, instead of driving all the way in traffic jams and wasting time for searching a parking space [45].

According to the study "Reduktion der Emissionsbelastungen bei Großveranstaltungen durch eine zielorientierte Verkehrsplanung am Beispiel der Weltausstellung EXPO 2000" [46], the average speed and emission were modeled under two different parking schemes for the EXPO visitors in Hannover. Table 3.2 shows that approximately halving of the EXPO parking places can increase the average speed by 25 percent and reduce $CO_2$ and CO emissions by 6.3 percent and 10.7 percent respectively.

**Table 3.2: Effects of different Parking Schemes for the EXPO visitors on Average Speeds and Emissions**

| Parking Places per Day | 36.5000 | 67.200 | % |
|---|---|---|---|
| **Average Speed at peak hour (km/h)** | 75 | 60 | 25 |
| **$CO_2$ (ton/day)** | 6818 | 7251 | 6.3 |
| **CO (kg/day)** | 50212 | 55604 | 10.7 |

Data Source: [46]

In addition, regulation of on-street parking can play an important role in achieving benefits for energy consumption and emission through reduce traffic congestion and smooth the traffic. This measure can influence the volume and nature of traffic by:

- Giving more road space to moving vehicles, and
- Avoiding reversing maneuvers by driving searching for parking spaces.

#### 3.3.3.5 Freight Traffic Management

Restrictions on heavy goods vehicle movements in cities, the establishment of goods distribution centers on the edges of towns and the Trans-shipment of consignments to specialized city trucks will help to reduce the impact of heavy lorries on urban traffic and the urban environment. Both within cities and in their surrounding regions, trucks are also a source of inconvenience and environmental burden. Despite the importance of urban freight transport, truck traffic has until now been greatly neglected in urban and regional traffic planning. However, new urban traffic concepts tend to include provision of lorry routes, limits on vehicle sizes and weights and temporary or permanent access bans. Such schemes are in operation in Bad Reichenhall, Salzburg, Heidelberg and other cities [41].

Fleet management, which means better logistics through information and communication technology, improves the efficiency of vehicles. Logistics tend to replace stock-keeping; e.g. just-in-time deliveries, displaced and dispersed production and goods supply [43].

Multi-modal freight centers and freight distribution centers are needed. Regional multi-modal freight centers (providing an interface between rail, road, water and air transport) are an indispensable prerequisite to increase the use of rail transport and achieve a more compatible freight distribution. City logistics and freight distribution centers are able to connect deliveries to individual companies and for certain delivery districts with smaller city trucks and, at the same time, to optimize round trips and the loading capacity of vehicles and delivery ramps (e.g. Bremen multi-modal freight center) [43].

#### 3.3.3.6 Introduction of Intelligent Traffic Systems (Telematics)

Telematics in traffic and transport is the key issue of all traffic management approaches, such as PROMETHEUS or DRIVE (European car manufacturers' programs), the Intelligent Vehicle Highway System (USA approach), STORM (Stuttgart), Co-operative Traffic Management (Munich). These projects raise hopes that the traffic problems of cities and their surroundings could be solved without major changes of transport policies [47].

The car manufacturers trust the "intelligent" car and road. Telematics promises computer-aided driving with highest efficiency and safety. Today's application of control technology on roads focuses on dynamic collective guidance and information systems. This means variable speed limits according to traffic volumes, congestion warnings with staggered speed limits at the queue's end, special speed limits when unfavorable conditions of road surface and weather occur, and traffic control in special situations such as accidents or construction sites [47].

Individual navigation aids like AUTO-SCOUT or TRAVEL PILOT might be helpful to find one's destination on irregular drives in unknown cities. But these systems have no or only little effect on traffic flow and traffic volumes unless they are combined with traffic management and route assignment [31].

The combination of individual route guidance and dynamic route assignment leads to the individual guidance and information systems whose best known representatives are EURO-SCOUT in Berlin, AUTOGUIDE in London and ADVANCE in Chicago. All three systems are similar in their setting of goals to use the road network more effectively in the sense of handling more cars with less delays [28].

Cars equipped with on-board computers communicate with traffic guidance computers through infrared transmitters along the road. The cars provide anonymous information about travel times and congestion delays, so acting as "driving detectors". Based on these actual messages, the traffic guidance computer transmits route recommendations [31].

# CHAPTER 4
# ENERGY PLANNING IN THE TRANSPORTATION SECTOR

## 4.1 Introduction

The estimation of the energy consumption in the transport sector is a very complex problem that requires consideration of many parameters such as: engine type, fuel quality, vehicle age, maintenance level, and the operating characteristics [47]. In addition, the analytical methods needed to evaluate the transportation energy consumption must be able to project the energy consumption under various policy options. It is therefore likely that other parameters, such as the new trends in vehicle technologies and alternative fuels, would also be required during the whole evaluation process. The main objectives of this chapter can be summarized as follows:

(a) identify the parameters affecting the energy consumption in the transport sector,
(b) present a procedure for estimating the transportation energy consumption and emissions in urban areas,
(c) predict the trend of transport energy consumption in the future
(d) prepare a recommendation catalogue for needed actions to reduce energy consumption,
(e) examine the concept of sustainable development of energy consumption.

## 4.2 Interdependence between Transportation Models and Energy Models

In general terms, the basic approach for estimating the energy consumption in the transport sector can be based on the equation [45]:

$$\mathbf{TEC = A \times E}$$

where,

TEC = the total energy consumption,
A = the amount of transport activity, and
E = the energy consumption rate per unit of activity.

This equation can be applied at every level, from a single vehicle to the whole fleet and from a single road to the whole network. The accuracy of every estimation method depends on the amount, type and quality of the data available. This data can be classified as:

1- transportation data, which are required to provide reliable data on transport activity and on the nature and pattern of this activity, and

2- energy data, which are required to provide reliable energy consumption per unit of activity in connection with vehicle characteristics and usage, which suit the transport patterns.

The first field attempts to build models from (a) economic models which define the activity as a function of the most significant economic variables and (b) network flow models which simulate the traffic on a transport network in conjunction with socio-economic modules.

Economic models estimate the average activity (e.g. pass.-km, veh.-km) at national scale, on a yearly or monthly basis. These models do not provide any information about the traffic characteristics. The required energy data is limited by the average fuel consumption rate per unit of activity.

In contrast, the network flow models can be classified into two main types: (a) macroscopic models and (b) microscopic models. The output data from the macroscopic models are the activity (e.g. veh.-km) with respective average speeds. The required energy data in this case is the fuel consumption rates as a function of average speeds. Microscopic models provide more details data about the time spent by vehicles in each driving mode: cruise, acceleration, deceleration, and idle. These models require more accurate energy data on fuel consumption rate for each vehicle type per unit of time while cruising, accelerating, decelerating, and idling. Figure 4.1 presents the output data from different transportation models and its requirements from energy models.

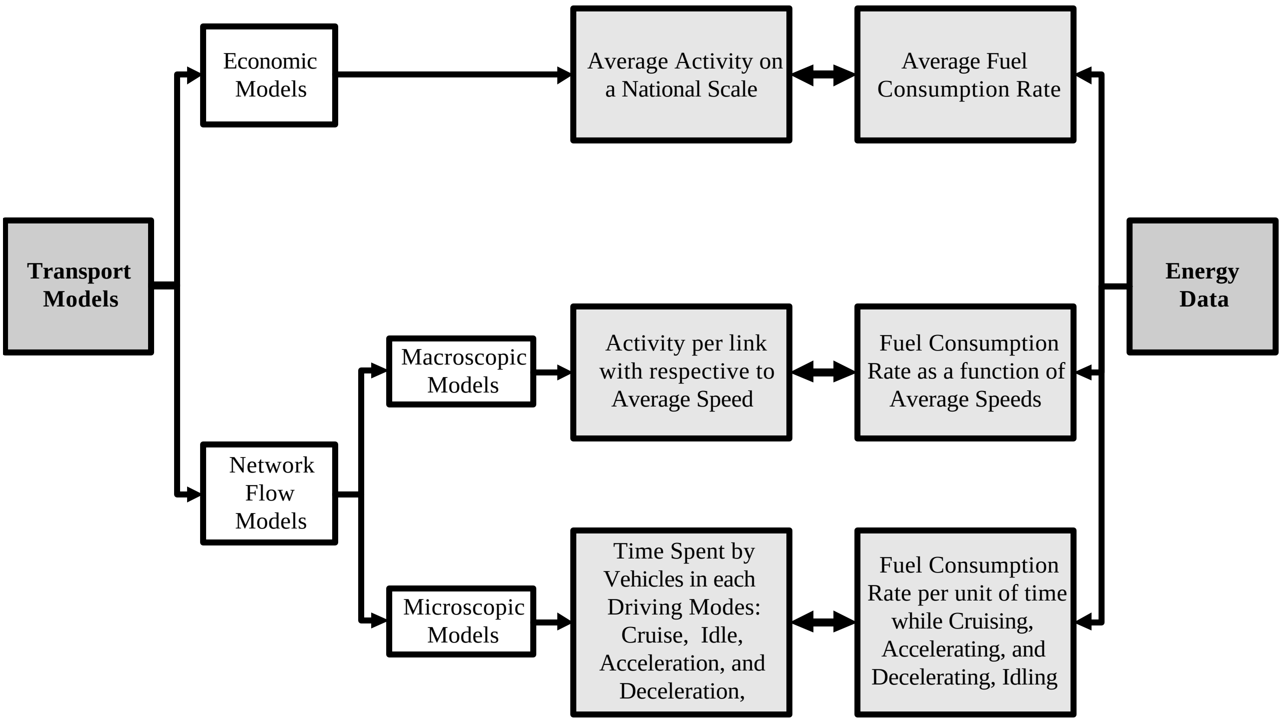



**Figure 4.1: Interdependence between Transport Models and Energy Models**

## 4.3 Estimation of Energy Consumption and Related Emissions

For the purpose of estimating energy consumption and related emission in urban areas, the structure of mobile sources should be selected to reflect the relative importance of the various sectors and the mechanized transport modes available within each sector. Mobile sources included in this procedure are road and rail transport. Road transport sector is divided into three modes: passenger car "P.C." (e.g. private car, taxi), light duty vehicles "L.D.V." (e.g. small buses), and heavy duty vehicles "H.D.V." (e.g. buses).

Since there are many different model years passenger car on the road, this mode are further classified by age of the vehicle. They are split into vehicle ages classes (e.g. >10 years old, 5-10 years old, and < 5 years old). Rail transport sector is divided into two modes train and tram. Figure 4.2 summarizes the structure of mobile source sectors, modes, and classes included in this procedure.

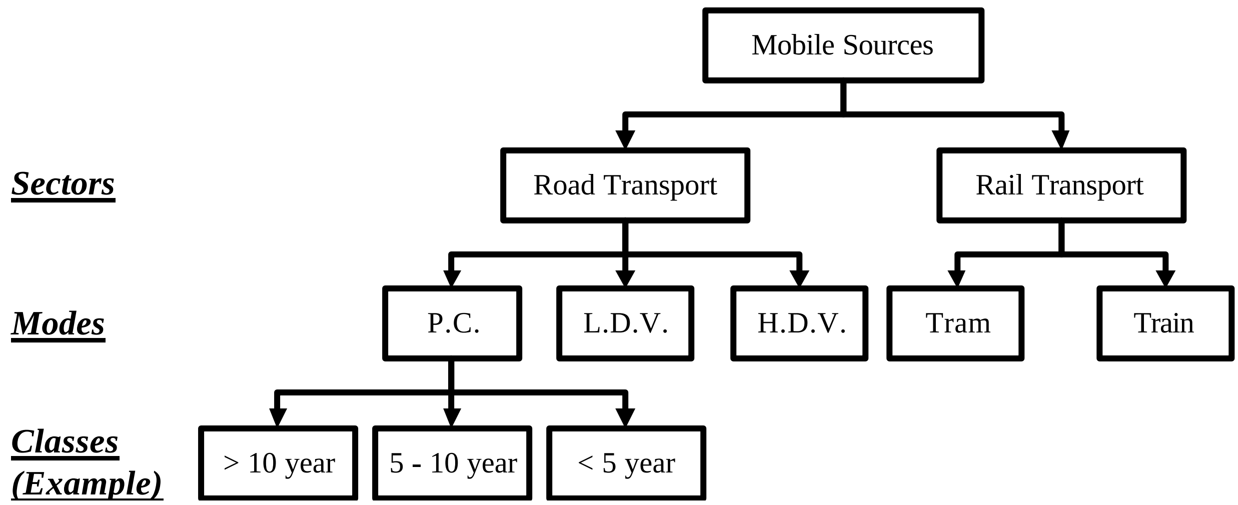



**Figure 4.2: Mobile Source Sectors, Modes, and Classes**

### 4.3.1 Road Transport

#### 4.3.1.1 Factors affecting Energy Consumption

Energy consumption from road transport is affected by a large number of parameters. The most important are:

*a) Vehicle Age and Technology*

Vehicle age affects the energy consumption and emission. The older vehicles have a much higher energy consumption rate because of deterioration and their older technology. As an example, a comparison between BMW 501, introduced in 1952, with a new BMW 5 Series, introduced in 1999, shows clearly the amount by which fuel consumption has been reduced although performance has risen at the same time (Table 4.1) [48].

**Table 4.1: Comparison between Old and New Technology for BMW (as an example)**

| Model | No. of Cylinders | Displacement (CC) | Power Output (bhp) | Weight (Kg) | Top Speed (km/h) | Fuel Consumption (l/100 km) at 90 km/h |
|---|---|---|---|---|---|---|
| **501** | 6 | 1971 | 65 | 1450 | 138 | 11.0 |
| **520** | 6 | 1991 | 150 | 1485 | 220 | 7.0 |

Source: [48]

The German-Swiss emissions model was developed in order to determine the energy consumption and emissions rates of all relevant categories of road vehicles in the two countries. Table A in ANNEX I presents, as an example, the classification for road vehicles according to the age and technology group that used in the German-Swiss emissions model [21].

*b) Operating Modes*

The operating mode of the motor vehicles is important because energy consumption vary significantly depending of which operating mode the vehicles in. The three operating modes are cold start mode, hot start mode and hot stabilized mode.

The start modes include the first few minutes of the operation after the engine has been operated. The difference between the cold and hot start modes is the time that the engine is shut off before being restarted. The hot stabilized mode contains all the time that the vehicle is in operation except for the start modes periods.

The variances in energy consumption rates between operating modes are primarily due to the fuel/air ratio. Energy consumption is high during the cold start mode, warm-up period, because the optimum fuel/air ratio, rich mixture, should be provided to receive sufficient performance from the engine [49]. Energy consumption rates for all fuel types are less during hot starts than for cold starts and are lowest during hot stabilized operation. The extent of the difference depends on a number of factors including the engine temperature and the trip length, and also various greatly from vehicle to vehicle [49].

*c) Vehicle Speed*

Many studies show a clear relationship between fuel consumption and speed [50, 51]. Under steady state, fuel consumption is particularly high at the extremes of high and low speed. Fuel consumption starts to rise at higher speeds, reflecting primarily the effect of aerodynamic resistance on fuel efficiency. At lower speeds, engine fraction and tires resistance increases the fuel consumption [50]. Figure 4.3 shows the relationship between steady speed and fuel consumption rates for three different vehicle types.

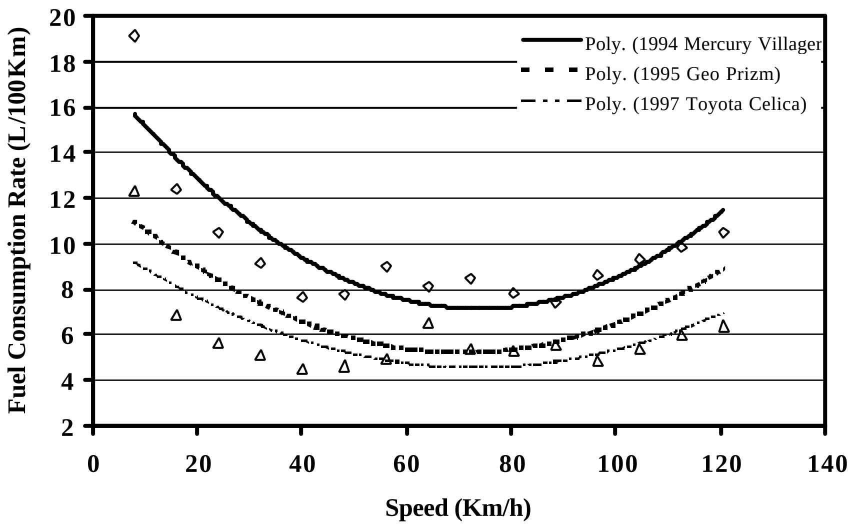



**Figure 4.3: Steady Speed/Fuel Consumption Curve [52]**

*d) Traffic Condition*

A single vehicle of a particular type has wide variations in fuel consumption rates depending on the traffic condition. The condition of traffic influence energy consumption rates because of the different driving modes (e.g. acceleration, deceleration, cruising and idling). Constant cruise speed, as shown in the previous section, has clearly effect on the energy consumption rates. Acceleration requires more power than cruising. Deceleration wastes kinetic energy through the engine and brakes. At idle, the fuel consumed does not produce any useful activity.

The fuel consumption rates at different traffic patterns are determined usually from the measurements on a chassis dynamometer, where the test vehicle is operated over a certain drive cycle while its energy consumption and emissions are collected and analyzed.

The most common way to describe the additional fuel consumption due to different traffic pattern is the use of average speed/fuel consumption curves. The characteristic shapes of these curves show high rates at both low and high average speeds. The highest energy consumption is associated with low average vehicle speed principally because of the frequent stops and starts, acceleration and deceleration. In the case of high average speeds, the large power demand on the engine lead to extensive energy consumption rates [49]. Figure 4.4 shows an example of the average speed/fuel consumption curve from the Germany passenger car 1998.

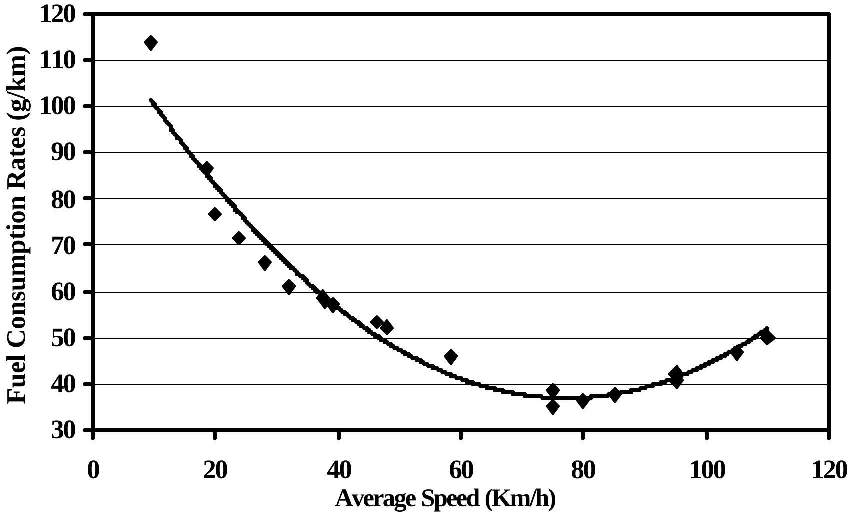



**Figure 4.4: Average Speed/Fuel Consumption Relationship [21]**

Different average speeds were classified and defined in the German-Swiss emissions model according to different situations. The energy consumption and emissions rates were determined at every average speed. Table B in ANNEX I presents, as an example, the detailed average speeds characterization that used in the German-Swiss model [21].

*d) Road Gradient and Vehicle Load*

Road gradient has the effect of increasing or decreasing the power required to propel any vehicle and accordingly increasing or decreasing the fuel consumption rates. It cannot be assumed, in the large applications, that the extra fuel consumption and emission when traveling uphill is fully compensated by the reduced fuel consumption and emission when traveling downhill [53].

Road gradients affect the energy consumption rates from passenger car, light duty vehicles, and heavy duty vehicles. Nevertheless, the overall gradient effect on passenger cars and light duty vehicles was found to be very small comparing with heavy duty vehicles principally because of their higher masses [53].

In addition, vehicle load affects the power needed, even in the zero slope case, fom the engine to overcome the resistance or the friction in the axles and wheels, especially in the case of the acceleration mode. As a result, the fuel consumption as well as the emission rates change according to the vehicle weight.

*e) Fuel Quality*

The heat content of a fuel is the quantity of energy released by burning a unit amount of that fuel. This value is not absolute and can vary according to several factors such as the chemical constituents and impurities in the fuel, both of which are affected by the combination of raw materials used to produce the fuel and by the type of manufacturing process. Temperature and climate conditions are also factors [52]. In addition, there are differences of the carbon content anticipated in the fuel used in the various countries. Hence, energy specific factors (e.g. Mj/km) and energy-specific emission rates (e.g. g/Mj) are recommended than the factors in grams/km or liter/km. Specific energy consumption and energy-specific emission rates should be country-specific whenever possible [47].

#### 4.3.1.2 Energy and Emissions Planning

Because energy consumption and pollutant emission from road transportation are influenced by a large number of parameters, it is virtually impossible to incorporate all these parameters into a single estimation procedure. Thus, for this procedure, only some of the most relevant parameters for energy consumption and emissions from traffic sources have been considered. The following factors are considered: (1) average traffic speed, (2) vehicle age (for private cars) and (3) fuel quality. The total energy consumption of each fuel type is calculated by [45]:

$$\textbf{Total Energy Consumption} = \Sigma\,(\textbf{SEC}_{\textbf{a,b,c}} \times \textbf{Activity}_{\textbf{a,b,c}})$$

where,

| | | |
|---|---|---|
| SEC | = | specific energy consumption (e.g. Mj per vehicle-km) |
| Activity | = | total transport activity (e.g. vehicle-km) |
| a | = | vehicle mode (e.g. P.C., L.D.V., etc.) |
| b | = | vehicle class (e.g. >10 years old, 5-10 years old, and < 5 years old) |
| c | = | fuel type (e.g. gasoline, gas oil, etc.) |

The emission level for each gas type from fuel combustion in the engines, using a specified fuel type, is calculated by [45]:

$$\textbf{Total Emission} = \Sigma\,(\textbf{SER}_{\textbf{a,b,c}} \times \textbf{TEC}_{\textbf{a,b,c}})$$

where,

| | | |
|---|---|---|
| SER | = | energy-specific emission rates (e.g. gram emission per Mj) |
| TEC | = | total energy consumption (e.g. Mj) |

Figure 4.5 presents the different steps of the proposed planning framework, which can be used for the calculation of total energy consumption and emissions from road transport in urban areas. The following basic steps are required:

1. Determine the total transport activity for each transport mode and class with respective to the average speed. These data can be obtained from the output of the four-step travel demand models (trip generation, trip distribution, modal split, and traffic assignment).

2. Determine the amount of fuel consumed by type at various average speeds for each transport mode and class using national data (gram or liter fuel/veh.-km).
3. Calculate the specific energy consumption for all transport modes and classes by fuel type (e.g., Mj/veh.-km).
4. Multiply the transport activity for each link by the corresponding specific energy consumption to compute the energy consumed by fuel type and transport mode (e.g., Mj).
5. Calculate the total energy consumed for the whole network by accumulating the energy consumed of each link by fuel type.
6. Determine the energy-specific emission rates for each fuel type, (e.g., gram emission/ Mj).
7. Multiply the total energy consumed for each fuel type and transport mode by its energy-specific emission rate to determine the emissions level (e.g., gram emission).
8. Energy and emissions can then be summed across all fuel to determine total energy consumption and emissions from mobile source-related activities.

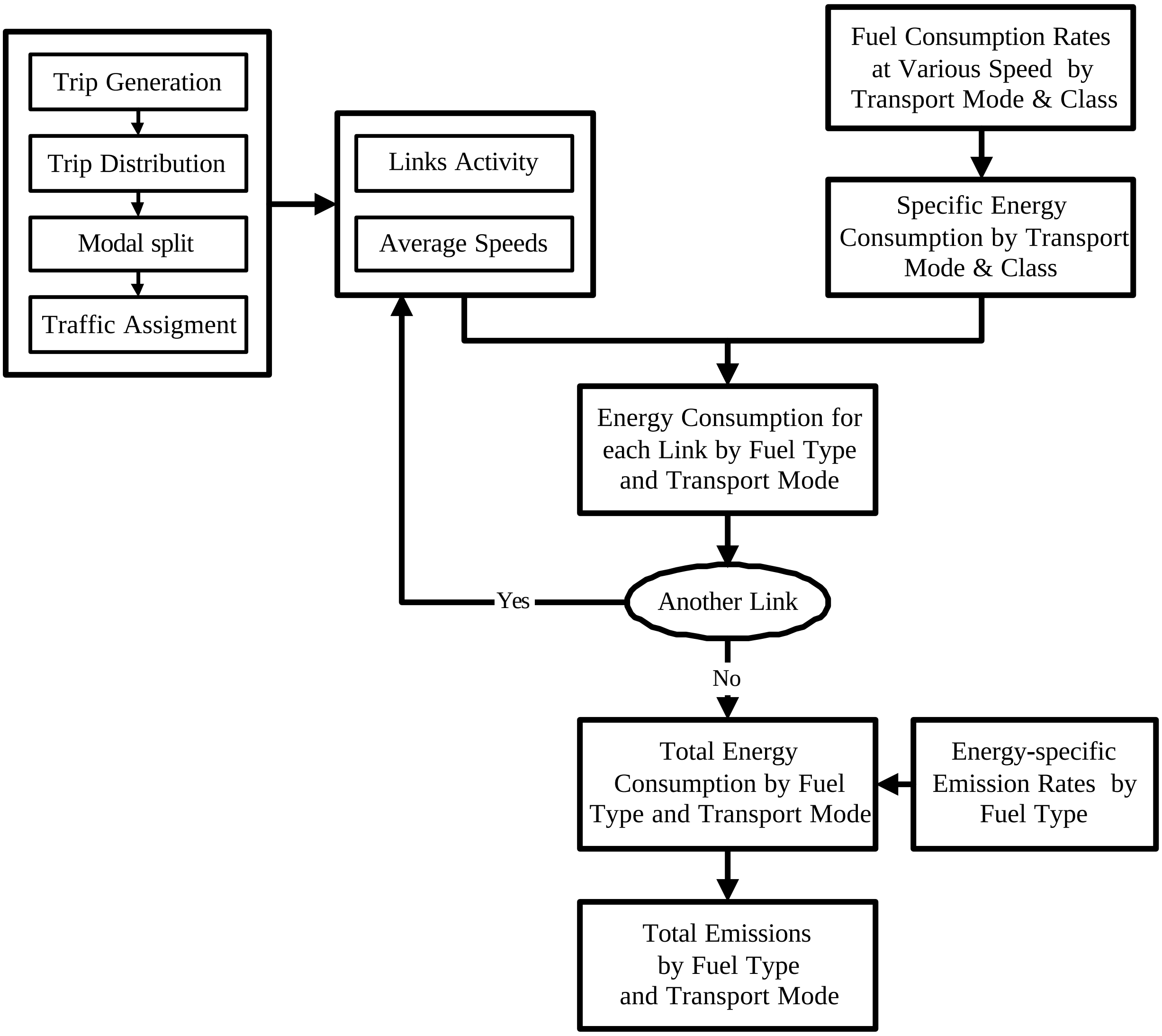



**Figure 4.5: Framework for calculating Energy Consumption and Emissions from Road Transport**

#### 4.3.1.3 The Computer System “TraEnergy”

One of the objects of this study is to provide link between transportation and energy fields. For this purpose, the computer system “TraEnergy” is developed to estimate road transport energy consumption and emission in urban areas. “TraEnergy” is written in visual basic for applications language.

The main advantage of this system that it is simple to run and can be applied to any urban area with different transport systems, fuel types and emissions as long as the input data can be provided. In addition, this program gives the possibility to examine different fuel type distribution (i.e. fuel switching) as well as different traffic conditions.

This system consists of four main modules. The first module (Initial Data Entry) is a data editor to introduce the links number, transport modes (number and names), fuel types (number and names), and emission types (number and names). The data is stored automatically on the computer disk from which it can be displayed on the screen, printed or modified.

The second module (Data Organization Management) is to introduce sheets data according to initial input data. Two types of sheets are created:

- Energy and emissions data sheet, in which tables are constructed according to the number and names of the fuel and emissions.
- Transport modes sheets, in which for each transport mode a separate sheet is constructed and named by the transport mode name (e.g. private car, bus).

The third module (Main Data Entry) is also a data editor for entering the output of the four-step travel demand models (links activity and speed) as well as the specific energy consumption and emission rates. The data is stored automatically on the computer disk from which it can be displayed on the screen, printed or modified.

The fourth module (Energy and Emission Calculation) is divided into two stages. The first stage is energy consumption and emission calculation for each link according to its average speed. The second stage is total energy consumption and emission calculation for the whole network for each transport mode. The fundamental structure of “TraEnergy” system is illustrated in Figure 4.6.

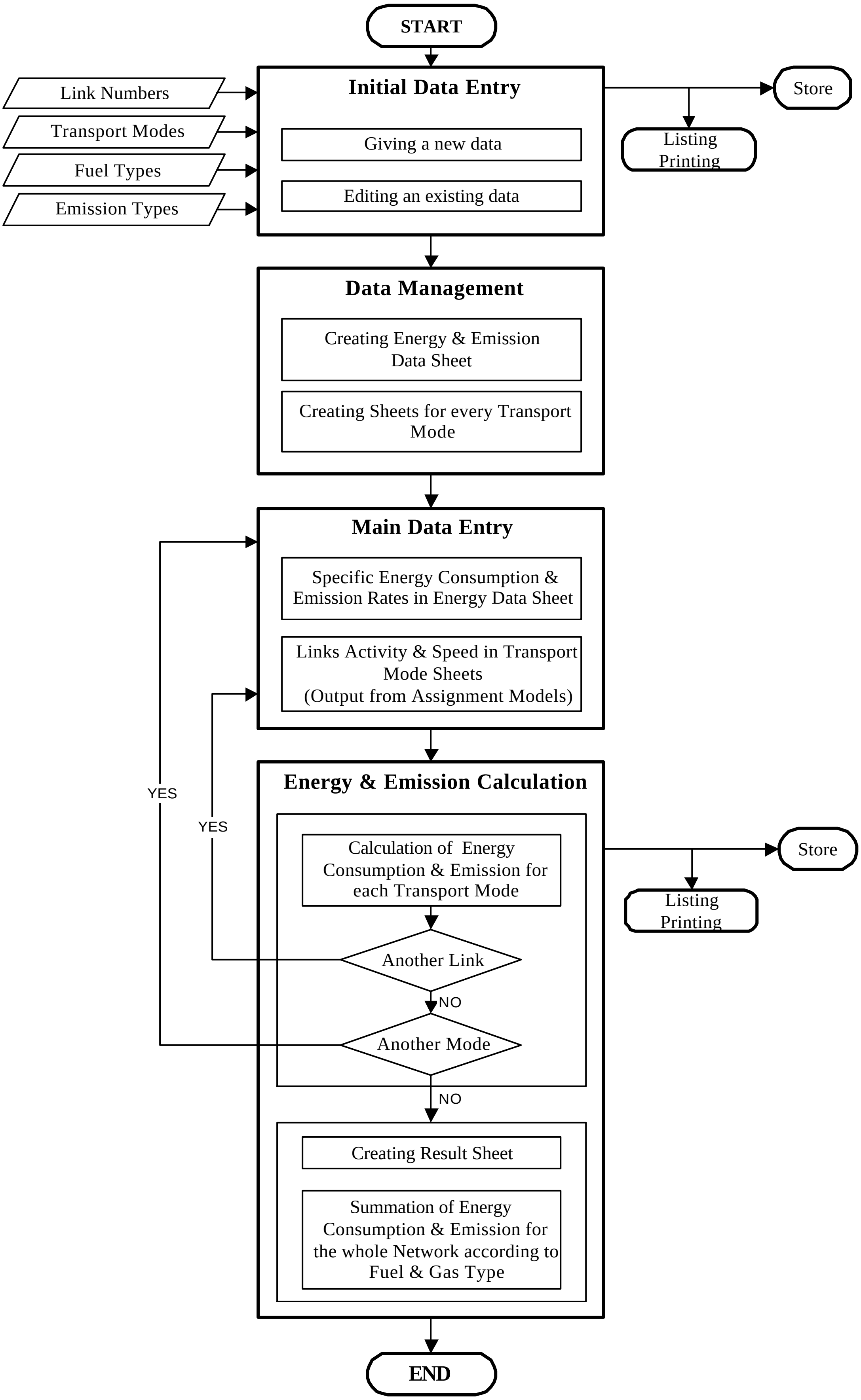



**Figure 4.6: The Fundamental Structure of TraEnergy System**

#### 4.3.1.4 Trends in Road Transport Energy Consumption

This section examines the new trends in road transport energy consumption and emission, such as new vehicle technologies and alternative fuels, which may have significant market penetration over the future.

*a) Near Future Vehicle Categories*

It may be technically possible, over the next 5 years, to reduce energy intensities for new vehicles of most types without reducing vehicle performance or the quality of transport provided [54]. Currently, only about 18 percent of the energy content of the vehicle fuel are available as shaft power for the road vehicles [49]. The rest of the energy is lost in overcoming internal friction by auxiliary items, in thermodynamic losses in the engine, etc. Because of these high loses, the potential to improve fuel economy with advanced technologies is enormous

Reductions of vehicle weight, improved aerodynamics, lower rolling friction for tires, down-sized engines, turbo-charging, lean-burn combustion, engine and catalyst preheating, direct fuel injection and electronic ignition controls have all been demonstrated as capable of increasing fuel efficiency and reducing emissions. Car manufacturers have worked intensively in order to improve vehicles efficiency. Table C in ANNEX I presents the potential reduction in energy intensity through the incorporation of some technologies [54].

*b) New Vehicle Technologies*

Many studies have been carried out to assess the technologies most likely be in use over the next 15-20 years and to provide the energy consumption and emissions rates they will produce. Candidate technologies that can be considered are: electric vehicles, hybrid electric vehicles, and fuel cell electric vehicles

- *Electric Vehicles (EV)*

Some characteristics of electric vehicles are superior to those of internal combustion engined vehicles. They are quiet, emission free at point of use, they do not use energy while stationary and do not incur warm up losses. Electric motors provide very high torque at low speeds and a wide speed range, and their efficiency is reasonably constant over their performance range. However, the performance and range of conventional electric vehicles is limited by the battery which accounts for a quarter of the vehicle's weight [55].

Most current electric vehicles use lead-acid or nickel-cadmium batteries, which are the longest established technologies. Lead-acid batteries are cheap and offer a long cycle life, but have low power and energy densities. Nickel-cadmium batteries have a higher energy density and longer cycle life, but their cost is more than three times greater than lead-acid, and there are also concerns over the large amount of cadmium that may be introduced into the environment. The most likely battery for future electric vehicles is the nickel-metal hydride, which has high power, and long cycle life, but is expensive in comparison with lead-acid [55]. The average specific energy consumption and emission factors “full energy cycle emissions” from the electric vehicles are presented in Table D in ANNEX I [56].

- *Hybrid Electric Vehicles (HEV)*

Hybrid electric vehicles combine the internal combustion engine of a conventional vehicle with the electric motor. This combination offers the extended range and rapid refueling that consumers expect from a conventional vehicle, with a significant portion of the energy and environmental benefits of an electric vehicle. Such vehicle could operate as a battery electric vehicle in short trips, while for long trips, the combustion engine would be the main source of power with the electric drive offering assistance when accelerating. In addition, the motor can work as a generator to feed energy to the battery [56]. Table D in ANNEX I presents the average specific energy consumption and emission factors “full energy cycle emissions” for gasoline hybrid electric vehicles [56].

- *Fuel Cell Electric Vehicles (FCEV)*

Fuel cells generate electricity by converting hydrogen fuel through an oxidation process into electricity. The process is an electrochemical reaction that is similar to the process which occurs in a normal battery. The hydrogen fuel can be obtained from any fuel that can be reformed to produce it [55]. Methanol and gasoline have received the most attention. The average specific energy consumption and emission factors “full energy cycle emissions” for methanol fuel cell vehicles are shown in Table D in ANNEX I [56].

*c) Alternative Fuels*

This section examines some of alternative fuels which expected to have significant market penetration over the next 15-20 years. The alternative fuels included are natural gas, liquid petroleum gas, methanol, ethanol, and biodiesel.

- *Natural Gas (NG)*

Natural gas is a mixture of hydrocarbons, mainly methane, and is produced from gas wells or in conjunction with crude oil production. The interest of natural gas as alternative fuel stems mainly from its clean burning qualities, its domestic resource base, and its commercial availability to end users. In addition, natural gas is a well tested alternative fuels around more than a million natural gas vehicles in use in the world mainly in Italy, Argentina and Former Union [56].

Natural gas can be used as a motor vehicle fuel either compressed in cylinders as compressed natural gas (CNG) or as liquefied natural gas (LNG). Liquefied natural gas is rarely considered since it is more expensive and more difficult to handle than CNG. Compressed natural gas is non-toxic, non-carcinogenic, and non-corrosive and can be used in either dedicated or dual-fuel engines [56]. Table E in ANNEX I presents the full cycle energy consumption and emissions from the compact natural gas vehicles [57].

- *Liquid Petroleum Gas (LPG)*

Liquefied petroleum gas consists mainly of propane, propylene, butane, and butylene in various mixtures. It is produced as a byproduct of natural gas processing and petroleum refining. The components of LPG are gases at normal temperature and pressures. The fuel is liquefied by compressing the gas to pressure (100 to 300 psi) in order to reduce its volume for storage and transport [56].

LPG is the most widely used of the alternative fuels, being used in over 3.5 Mil. vehicles worldwide, mainly in Italy, the Netherlands, France, Belgium and Spain. Most LPG fuelled vehicles in use are petrol-fuelled vehicles that have been converted, or hybrids which allow the driver to switch between LPG and petrol. LPG is cheaper than petrol per unit volume but it has lower energy content [56]. Table E in ANNEX I presents the full cycle energy consumption and emission from the liquefied petroleum gas vehicles [57].

- *Methanol and Ethanol*

Methanol and Ethanol have many desirable combustion and emission characteristics because of their low vapor pressure and high octane number. In addition, most vehicles designed to run on methanol and ethanol can operate on any combination of petrol and methanol from a single tank with few modifications [56].

Methanol can be produced from natural gas, coal or biomass. At current prices the most economical feedstock for methanol production is natural gas [56]. Ethanol can be produced by processing agriculture crops, such as sugar cane or corn, but it is more expensive to produce than methanol and requires large harvests of these crops and large amounts of energy for its production. Disadvantages of methanol and ethanol include the low energy density which mean that roughly twice the mass is required to give the same power output as gasoline. Table E in ANNEX I presents the full cycle energy consumption and emission from methanol vehicles [57].

- *Biodiesel*

Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from vegetable oils and animal fats [56]. Many initiatives have been taken in the US and Europe to support biodiesel because they are renewable energy sources. Advantages for biodiesel in comparison with fossil diesel are less sulfur and aromatic content and higher cetane value. Disadvantages include the lower heating value and the higher freezing point. Table E in ANNEX I presents the full cycle energy consumption and emission from the biodiesel vehicles [57].

### 4.3.2 Rail Transport

#### 4.3.2.1 Factors affecting Energy Consumption and Emissions

Energy consumption and emission from rail transport is affected by a large number of factors. The most important are:

*a) Type of train: Electric or Diesel*

In general, electric power generation have a bitter utilization of the energy and their emissions are produced at remote sites, and not from the location of the train itself, as in the case for diesel powered trains. There are also minor differences in train weights due to differences between the weights of electrical and diesel powered locomotive.

Table 4.2 presents comparative data about energy use and some atmospheric emissions from different types of trains. The data here is representative only but do provide evidence as to the order-of-magnitude involved. There are very wide variations in these data, because of the different assumptions made about the composition of the fuels used, the different operating conditions, and the train loading factors. But the clear inference is that electric train transport is cleaner in terms of all emissions. It should be also noted that the pollutants derived from electricity generation needed for electric trains are also considered in the data in Table 4.2.

**Table 4.2: Energy Use and Atmospheric Emissions from Trains**

| Train Type | Consumption (Kj/Pass.-km) | Gram / passenger-km | | |
|---|---|---|---|---|
| | | CO | HC | NO |
| **Conventional diesel** | 900 | 1.70 | 1.24 | 0.87 |
| **Conventional electric using coal generation** | 850 | 0.13 | 0.076 | 1.00 |
| **TGV- type electric using coal generation** | 820 | 0.03 | 0.015 | 0.23 |
| **TGV- type electric using coal generation with emission control system** | 820 | - | 0.003 | 0.19 |
| **TGV- type electric using oil with emission control system** | 800 | 0.013 | - | 0.26 |
| **TGV- type electric using natural gas with emission control system** | 800 | 0.006 | - | 0.25 |

Source: [58]

*b) Acceleration/Inertia Force and Gradient Effect*

Train weight is the most significant parameter in determining the energy consumption and emissions. It affects the power needed, even in the zero gradient case, from the engine to overcome the resistance. Under acceleration, the energy consumption is directly related to the accelerated mass. The acceleration energy plays a dominating role in the urban traffic because of the short distance between stations and traffic restrictions along a route. Table F in ANNEX I illustrates comparison between Danish IC3 train used in interregional and urban traffic [59]. It can be shown that energy consumption in the case of urban traffic is about three times the energy consumption in the case of interregional.

In addition, rail gradient has the effect of increasing or decreasing the power required to propel the train and correspondingly increasing or decreasing fuel consumption rates. The uphill gradient resistance is constant irrespective of speed and thus simply adds to the train resistance. When the train is going downhill, this figure is subtracted from the train resistance.

*c) Tractive Effort*

Tractive effort is the force delivered by the motive power of the locomotive in order to cause movement. This force depends on the characteristic of the power equipment installed on the train, and how the driver uses it. The tractive effort is not constant throughout the speed range, and most traction units have a characteristic that looks something like Figure 4.7. The figure shows that the tractive effort is constant up to significant speed “knee point”. Therefore, in this speed range, the acceleration is constant and speed will build up uniformly with time. This is the region of maximum tractive effort. After this speed range, the tractive effort falls, and in consequence the acceleration will start to fall and speed will not build up so quickly.

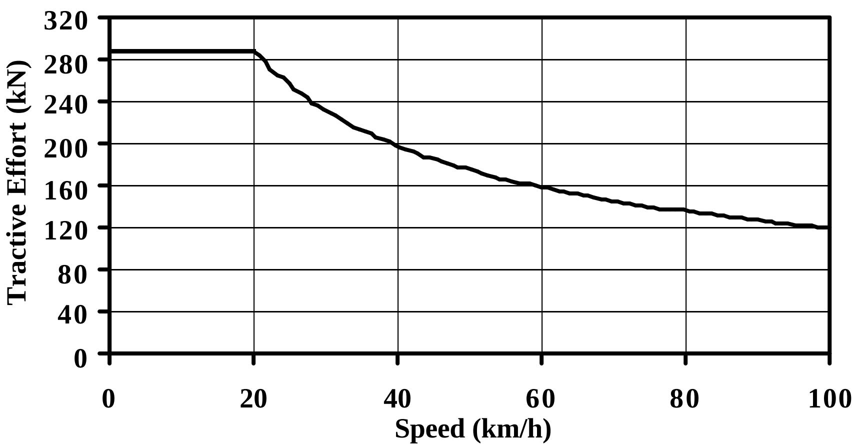



**Figure 4.7: The Relationship between Tractive Effort and Train Speed**

The product of the speed and the tractive effort is power. In the region of maximum tractive effort, the power continues to rise throughout the speed range. When the maximum power capability of the equipment is reached, at knee point, the tractive effort starts to reduce as speed increases to compensate. Figure 4.8 shows an example for the power throughout the train speed.

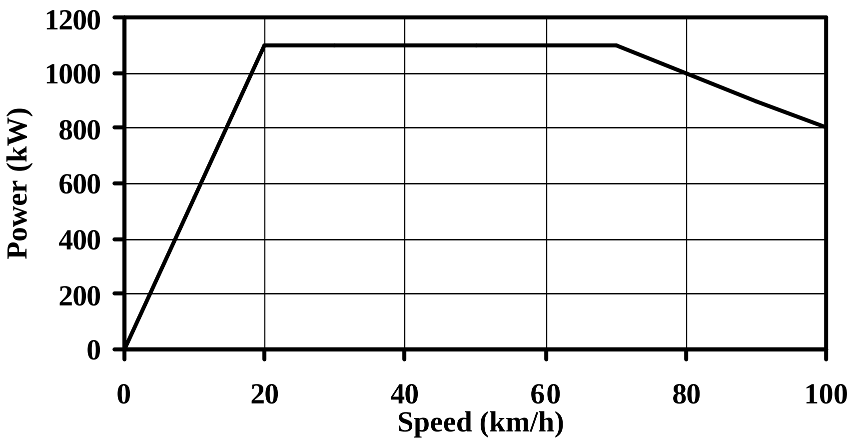



**Figure 4.8: The Behavior of the Power throughout the Train Speed**

*d) Resistance*

The train has to overcome a number of resistances beside the acceleration/inertia force. These resistances include bearing resistance, aerodynamic resistance and rolling resistance.

- *Bearing Resistance*

The bearing resistance depends on the speed of rotation, intensity of bearing pressure and method of lubrication. The higher values of resistance observed at starting are associated with bearing resistance, and are due to the need of a certain amount of rotation to establish proper lubricating conditions [59]. The power required to overcome the bearing resistance is linear with respect to the train speed.

- *Aerodynamic Resistance*

Aerodynamic resistance is strongly dependent on the train speed. It depends also on the aerodynamic shape of the bodywork, as well as on the shape, the formation, and the length of the train. Aerodynamic resistance increases in proportion to the square of the speed [58]:

$$\mathbf{W_a = CV^2}$$

where,

$W_a$ is the aerodynamic resistance of the train, V is the speed, and C is parameter depends on the shape of the train's front and the surface type.

- *Rolling Resistance*

Rolling resistance is the contact resistance between wheel and rail. It depends on train weight, train speed and total number of axles. Most rolling resistance is produced at the surface of contact between wheel and rail and, it results from the following forces (Figure 4.9) [58]: (1) lateral and longitudinal creep forces X and T, (2) reaction of the vertical static and dynamic forces N, and (3) guidance forces F exerted at the point of contact between the inner gauge of the rail and the wheel flange.

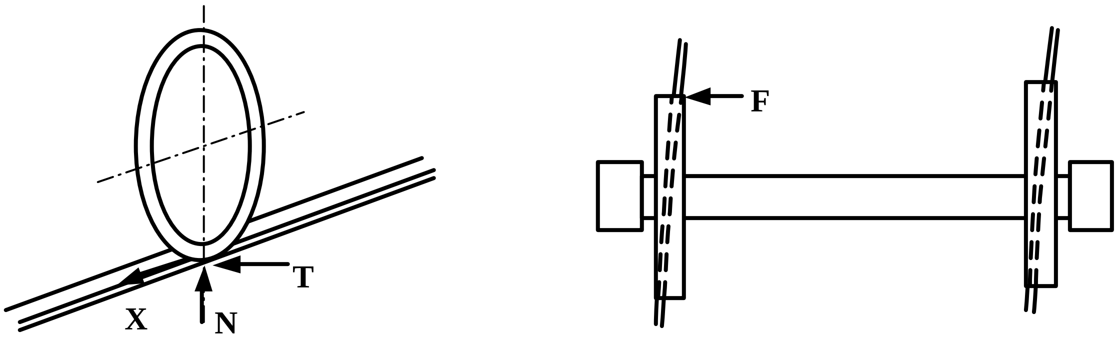



**Figure 4.9: Lateral, Vertical, Longitudinal, and Guidance Forces**

#### 4.3.2.2 Energy and Emissions Planning

Calculation of energy consumption and emission from rail transport is different than road transport. Due to the large number of road vehicles, energy consumption from road transport required laboratory data for a sample of vehicles to produce appropriate fuel consumption factors. In the case of rail transport the number of operated vehicles and routes, in urban areas, is very limited in comparison with roads. Therefore, for every train type and route the total power "e.g. kWh" required to move this train for a variety of situations can be calculated using dynamics models or empirical equations. The required data are:

- Route data (e.g. gradient, radius, stations stops, speed limits, etc.).
- Train data (e.g., locomotive types and number, train weight, brake system).
- Traction units (e.g. typical bearing resistance and rolling resistance, etc.).

The energy consumption per trip (e.g. Mj/trip) for a significant train type can be determined using appropriate fuel factors in Mj/kWh of power produced. Then, the total energy consumption can be calculated by multiplying the number of trips with the found energy consumption per trip.

$$\textbf{Total Energy Consumption} = \Sigma\,(\mathbf{SEC_{a,b} \times NTS_{a,b}})$$

where,

| | | |
|---|---|---|
| SEC | = | specific energy consumption (e.g. Mj per train-trip) |
| NTS | = | number of trips (trip) |

a = railway modes (e.g. train, tram, etc.)

b = fuel type (e.g. gas oil, etc.)

The emission level for each gas type from fuel combustion in the engines, using a specified fuel type, is calculated by:

$$\textbf{Total Emission} = \Sigma\,(\textbf{SERa,b} \times \textbf{TECa,b})$$

where,

SER = energy-specific emission rates (e.g. gram emission per Mj)

TEC = total energy consumption (e.g. Mj)

Figure 4.10 presents the different steps of the proposed planning framework, which can be used for the calculation of total rail energy consumption and related emissions.

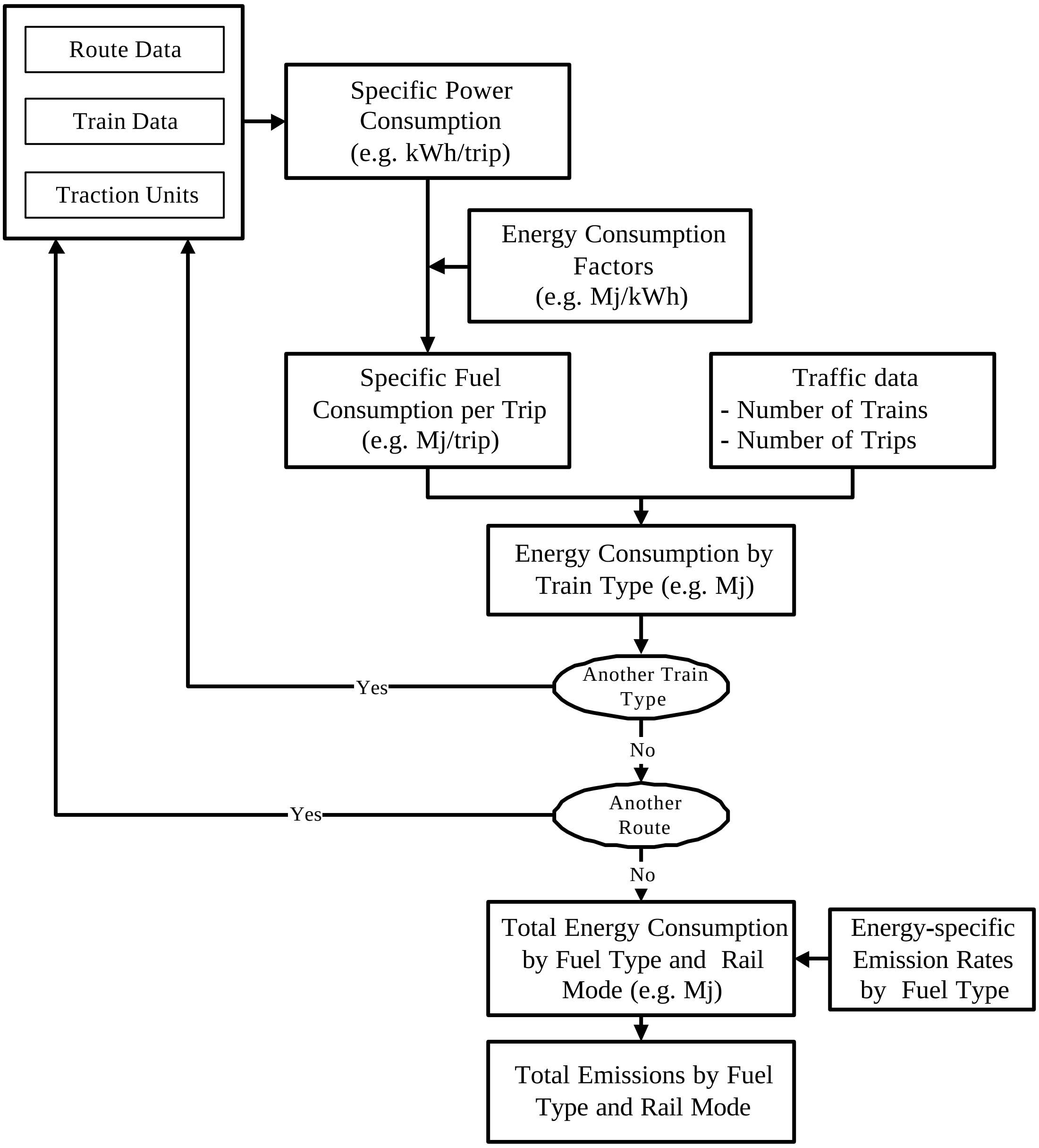



**Figure 4.10: Framework for calculating Energy Consumption and Emissions from Rail Transport**

#### 4.3.2.3 Trends in Rail Transport Energy Consumption

*a) Train Construction*

Any reduction in train weight will reduce the inertia and rolling/bearing resistance. Weight reductions can be achieved either by improving construction to use less material or using materials with a lower density like ultra high strength steel or/and aluminum [60]. Passenger train weight is often expressed as the specific weight per seat. Table G in ANNEX I presents the specific weight for advanced trains which are expected as the market standard in the future.

*b) Power Technology*

- *Diesel engine technology*

A large amount of effort has been expended in reducing energy consumption and related emissions from diesel engines. The required technologies for reducing the energy consumption and its related emissions for the diesel engines have been driven by the requirements for less energy consumption and polluting road vehicles [55].

- *Electricity generating technology*

Since most of the rail traffic is powered by electricity, it is necessary to examine the development in energy consumption and its related emissions to generate electricity. Technologies include conventional thermal generation (coal, oil and gas), nuclear power, hydropower and other renewable sources. Furthermore, the energy consumption and emissions depend strongly on the efficiency of the plants considered. While the air pollutant emissions from nuclear and hydroelectric power generating units are minimal, the have been substantial emissions of other substances from combustion power plants [60]. The emissions for power generation reflect these differences, and the countries with low amounts of nuclear end hydroelectric power typically have much higher emissions. The two emissions of main concern with power plant operation are NOx and $SO_2$ emissions [55].

### 4.4 Developing a Recommendation Catalogue for needed Actions to Reduce Energy Consumption and Emissions

Table 4.3 presents different measures that may be needed by preparing a program for reducing the urban transportation energy consumption and emissions. The table also shows the impacts of the individual measures.

**Table 4.3: The Recommendation Measures for the Reduction of Transport Energy Consumption and Emissions and its Impacts**

| Measure / Impact | | Modal Shift | Travel Demand | Traffic Condition | Fuel Switching | Fuel Intensity |
|---|---|---|---|---|---|---|
| **M1** | Integrated land use/transportation planning | ◑ | ● | ◕ | ○ | ◔ |
| **M2** | Upgrading public transport systems | ● | ○ | ◕ | ◔ | ◑ |
| **M3** | Creation of Pedestrian facilities | ● | ◑ | ◕ | ○ | ○ |
| **M4** | Environment-oriented improvement of road network and the introduction of automatic traffic Signaling | ○ | ○ | ● | ○ | ◕ |
| **M5** | Road pricing / road licensing / parking restrictions | ● | ◑ | ◕ | ○ | ○ |
| **M6** | Traffic priorities for bus and High Occupancy Vehicles | ● | ○ | ◔ | ◔ | ◕ |
| **M7** | The introduction of freight transport centers | ○ | ○ | ● | ○ | ○ |
| **M8** | Introduction of new urban-regional railways systems | ● | ○ | ◕ | ◔ | ○ |
| **M9** | Maintenance of vehicles to the manufacturer's specifications | ○ | ○ | ○ | ○ | ● |
| **M10** | Higher registration fees | ● | ◑ | ◕ | ○ | ◔ |
| **M11** | Higher fuel price | ● | ◑ | ◕ | ○ | ◔ |
| **M12** | Monthly fix-rate of fuel per vehicle | ● | ◑ | ◕ | ○ | ◔ |
| **M13** | Information Programs on efficient Vehicle Use for Vehicle Drivers | ◑ | ◔ | ● | ○ | ◕ |
| **M14** | Effective use of telecommunications | ○ | ● | ◕ | ○ | ○ |
| **M15** | Vehicle Scrapping Program | ◕ | ○ | ◑ | ◕ | ● |
| **M16** | Ride Sharing and Car Pooling | ● | ○ | ◕ | ○ | ● |
| **M17** | Fuel Efficiency Standard (improving fuel quality) | ◕ | ○ | ◑ | ◕ | ● |
| **M18** | Increased the use of Alternative Fuels in the Vehicle Fleet | ○ | ○ | ○ | ● | ● |
| **M19** | Electric car / Electric bus | ○ | ○ | ○ | ● | ● |
| **M20** | Solar Energy | ○ | ○ | ○ | ● | ● |

● Primary Impact…… ○ Nothing

## 4.5 Evaluation Process for Projecting the Transportation Energy Consumption and Emissions under different Policies

Figure 4.11 illustrates the multi-stepped process proposed to evaluate different policy techniques. Based on the transport activities, the expected vehicle stock and the new technology trends, the energy consumption and emissions (in the target year) can be calculated.

Then, different scenarios for reducing the energy consumption are prepared and analyzed. Each Scenario may contain an abatement measure or a set of measures (i.e., combination of measures from the catalogue in Table 4.3). The scenarios should be compared with each other as well as with the so-called "reference scenario". The reference scenario is defined as the solution that is based on the authorized transportation master plan, if available, and/or "business as usual" travel behavior.

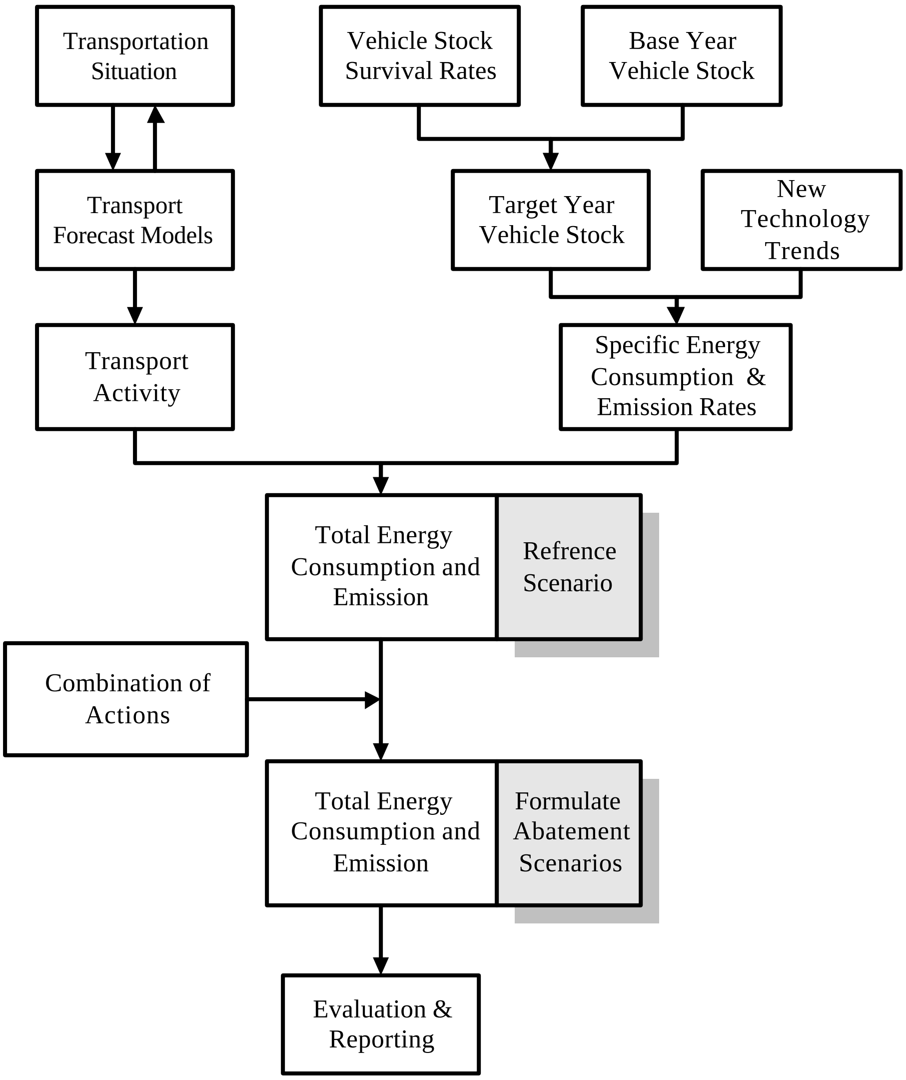



**Figure 4.11: A Multi-stepped Process for the Evaluation of Policies Techniques**

For the calculation of the transport activities, travel demand models are needed. The models can also be applied to predict the effects of measures with "modal shift and travel demand reduction" objectives. It is very difficult to predict the effects of the measures with other objectives, such as fuel switching, energy saving, public education of vehicle drivers, and vehicle maintenance. In this case, the measure effects can roughly be estimated by applying limited experiments or by investigating the results obtained from countries which already carried out such measures [31].

In addition, it is important that the model should have an indication of the nature and magnitude of the effects of changes in the many factors that contribute to energy consumption models.

Some procedures should be developed to improve the data quality and to resolve uncertainties affecting emission estimates. This may involve the use of standard deviations, ranges of uncertainties, or some other means of indicating the reliability of the data. This issue must receive additional attention in any follow-up process [31].

## 4.6 Sustainable Development of Energy Consumption (Towards Sustainability)

Sustainable development of energy consumption can only be achieved with the aid of drastic policies because:

1- The spatial patterns of activities and economies tend to
   - improvement in the quality of living and rises in personal income, which lead to
     - increase in private car ownership,
     - decrease in the use of public transport and
     - decrease in car occupancy.
   - growth in urban activities and dispersion of the population, which lead to
     - increases of mobility and
     - more transportation policies, concerning congestion and accidents, which sometimes result in more energy consumption.

2- The majority of transport energy consumption will come in the next years from those countries that are currently developing rapidly or that have economics in transition (e.g. China).

3- Policies which are aimed mainly at improving the efficiency of the energy chain, will probably not achieve the required reduction in energy consumption, because of these feedback loops
   - an improvement in efficiency will lower the price of energy which will in turn encourage the use of energy and thus cancel out part of the efficiency gain.
   - auxiliary equipment, particularly air conditioning, tends also to reduce efficiency gains.
   - higher safety standards mean that vehicles are heavier and use more fuel.

4- Crude Oil (as indicated in Chapter 2), the essential energy input for transportation, is being used at a rate 100,000 times faster than they are being formed. According to best estimates, there are currently 143,000 Mil. tons of recoverable oil left on earth, enough to continue about 41 years at present consumption rates.

To achieve sustainable development at least two different sets of objects need to work together (Figure 4.12):

1- *Push-Down* the growth in energy demand through:
   - Developing higher prices for private car use (pricing measures)
   - Forcing the improvement of efficiency in order to overcome the feedback loops identified by strong financial investments.
   - Reducing the use of private car through switching to non-motorized transport modes, public transport, and substitution of transport (telecommunications), together with behavior change.
   - Avoiding transportation policies, concerning accidents and congestion, which lead to more energy consumption.

2- *Push-Up* the energy supply through:
   - Switching to alternative fuels, including renewable energy, by providing strong financial incentive.

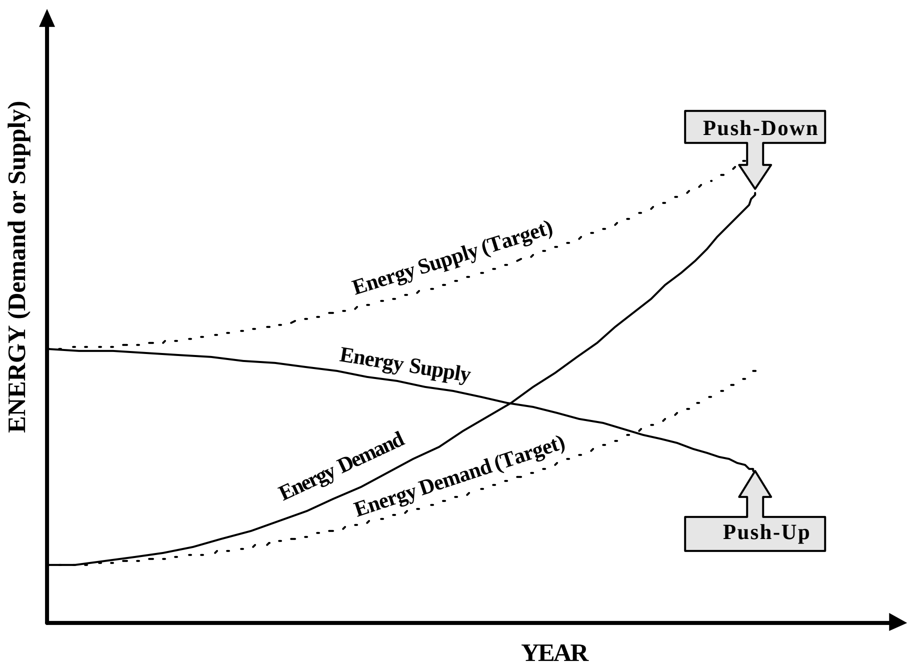



**Figure 4.12: Towards Sustainable Energy Consumption (Push Up & Down Approach)**

# CHAPTER 5
# THE PRESENT SITUATION OF THE TRANSPORT SECTOR IN ALEXANDRIA

## 5.1 General

The Arab republic of Egypt is administratively divided into 26 economics regions. Alexandria with about 3.7 Mil. inhabitants, is the second largest one. Alexandria is located on the northwestern edge of the Nile Delta, where it developed on linear pattern between the Mediterranean coast and Lake Maryt. Favored by the coastal situation, Alexandria has over the course of time become the most important and the largest port of the country. It is not only a main port but also a major industrial city and a prime summer resort for domestic tourism. The main objectives of this Chapter are to present and analyze the urban structure and transportation situation of Alexandria.

## 5.2 The Urban Structure of Alexandria

Most data about Alexandria in this work are based on the study "Introduction of Regional-Urban Railway System in Alexandria, 2000" [35] as well as on the study "The Underground Transport System as a Mitigation option for GHG-Emissions" [61].

### 5.2.1 Population and Densities

The population of the Alexandria Governorate was approximately 3.4 Mil. inhabitants in 1996. Alexandria Governorate's share of national population has slightly increased from 6.1 percent in 1986 to 5.6 percent in 1996. However, its share of national urban population has declined over the same period from 14.5 percent in 1986 to 13.1 percent in 1996. This may be a result of greater increase in other urban areas. Alexandria Governorate's annual growth rate has been steadily declining. It reached a peak of 3.47 percent during the period from 1947 to 1960, and 1.37 percent during the period from 1986 to 1996.

The Alexandria Governate is subdivided into six zones. These are further broken down into fourteen districts (Kisms or Zones) and numerous sub-kisms (Figure 5.1). According to the census 1996, the population densities in the residential areas by kism (administrative districts) are very high and vary between 60 000 and 160 200 persons/km$^2$.

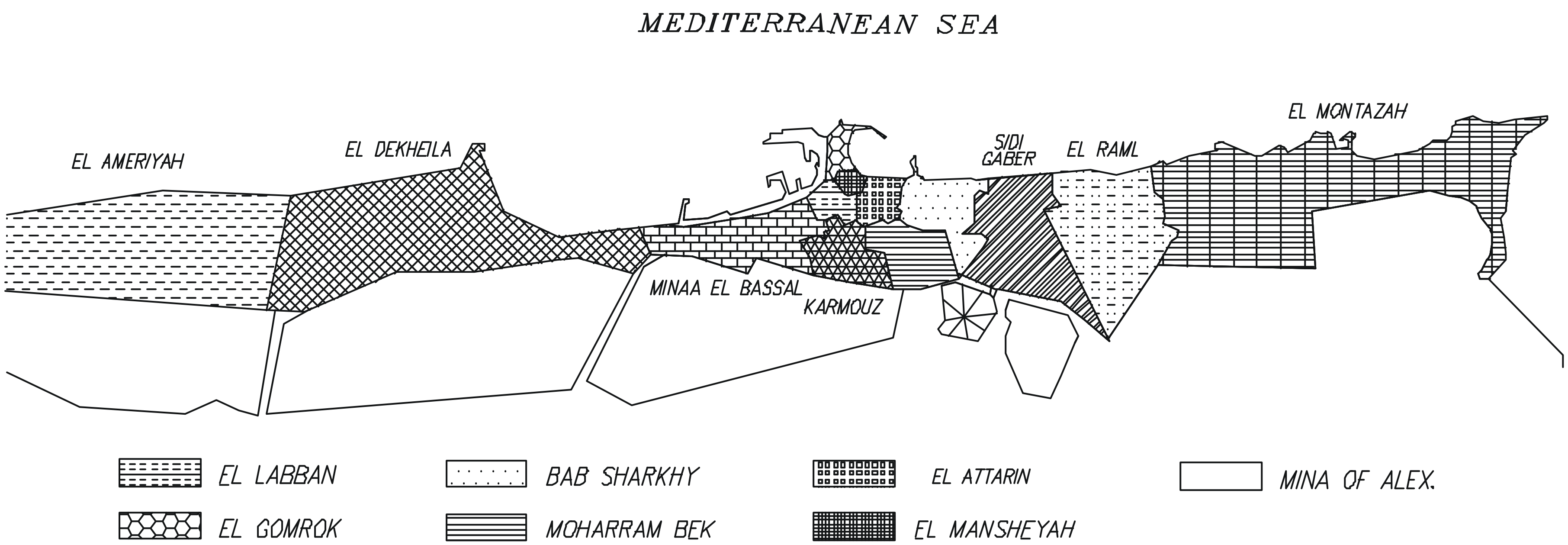



**Figure 5.1: Alexandria Kisms (Zones) [35]**

Table 5.1 compares kism population and percent change during 1986–1996. In the east, expansion of coastal activities of industrial development has encouraged urban development. Growth in the western part of the city is related to the progress of industrial and port activities. Central kisms, with the exceptions of Moharram Bek, which has open space for possible expansion, are more or less saturated and consequently the number of population has strongly decreased.

**Table 5.1: Kism Population and percent Change, 1986 - 1996**

| Kism | Population (x 1000) | | |
|---|---|---|---|
| | 1986 | 1996 | Percent |
| 1. Minaa El Bassal | 299 | 300 | 0.3 |
| 2. Mina of Alexandria | -- | -- | -- |
| 3. Gomrok | 122 | 124 | 1.6 |
| 4. Labban | 64 | 64.3 | 0.5 |
| 5. Karmouz | 196 | 197.5 | 0.8 |
| 6. Ameriya | 110 | 170 | 54.5 |
| 7. Dekheila | 97 | 110.8 | 14.2 |
| 8. Mansheyah | 38 | 39 | 2.6 |
| 9. Attarin | 65 | 67.4 | 3.7 |
| 10. Moharram Bek | 343 | 390 | 13.7 |
| 11. Bab Sharkhy | 203 | 227.6 | 12.1 |
| 12. Sidi Gaber | 159 | 180 | 13.2 |
| 13. Raml | 612 | 650 | 6.2 |
| 14. Montazah | 607 | 850 | 40.0 |
| **Total** | **2915** | **3370** | |

Source: [61]

As Alexandria is the foremost center of Egyptian domestic tourism, it has a high seasonal population during summer months. The peak seasonal population is estimated to be about 25 % - 35 % in excess of the permanent population. About one-half of the seasonal population is concentrated along the eastern coast. Dekheilah Kism to the west is also an important center of tourism.

### 5.2.2 Economic Activities

In 1996, only 26.6 percent of the total population was gainfully employed. The reasons for this low employment rate can be explained as follows:

- the rapid population increase,
- only 7.4 % of females were found to be economically active, and
- the age-structure of the population, about 60 % of the population was under 20 years of age.

Alexandria accounts for more than one-third of the national industrial stock. Its mix is widely diversified and includes textiles, chemicals, dyes, paper and printing, metallic, engineering machinery, basic steel, cement, oil refineries and food processing.

### 5.2.3 Land Use

The city of Alexandria was originally founded in 332 B.C. as an important port at the Mediterranean Sea north of Lake Maryut. The development of Alexandria is restricted to a narrow coastal stretch by the fact that it is located between the sea to the north, Lake Maryut to the south and rich farmland to the Southeast. Initially, the city developed to the east for as long as building land was available, but later it had to turn to the west for both housing and industrial needs. Today, the buildings area extends some 60 km along the Mediterranean coast, but its breadth is still limited to an average of 1 to 5 km.

The Alexandria Governorate (Figure 5.2) encompasses an area of approximately 2679 km$^2$, of which 46% desert, 28% arable land, 16% urban development and 10% water. These percentages, however, are in a continual state of change. Prime agricultural land is increasingly changing, desert land is being converted to agricultural use, inland water basins are being filled in for urban or agricultural functions and urban areas are rapidly expanding.

Between 1976 and 1996, the urbanized area in the governorate increased by 30 percent on the cost of both desert (Ameriya) and arable land (Sidi Gaber and Montazah). Agricultural land use also increased by seven percent through efforts in land reclamation.

Inland water basins in the Alexandria region include Lake Maryut and both the waterways of Mahmoudia and Nobaria Canals. Lake Maryut basin, due to its proximity to the open areas of the port to the west, is an attractive location for water- linked industries, both as a source of water and discharge of waste. Inland waterways in the Alexandria region have played an important role in the current patterns of land use. They provide the urbanized areas with a source of potable water and bulk water both for industrial and agricultural purposes. They are also used as transport corridors. The canals, particularly the Mahmoudia Canal, have stimulated a series of industrial and residential development including brick factories and informal housing.

Residential land use is the most dominant in Alexandria in the older and central parts of the city, along transportation corridors, and at the port area. It is difficult to segregate residential land use from other urban functions. Commerce and workshops are often completely mixed with residential use. There are two basic types of residential land use which serve both the permanent population and the seasonal increase. Residential land use serving the seasonal population is concentrated in Dekheila (Agami), Montazah and along the coastal beach areas from the old port to Montazah, on the other hand, is a mixture of hotels and high rise apartments.

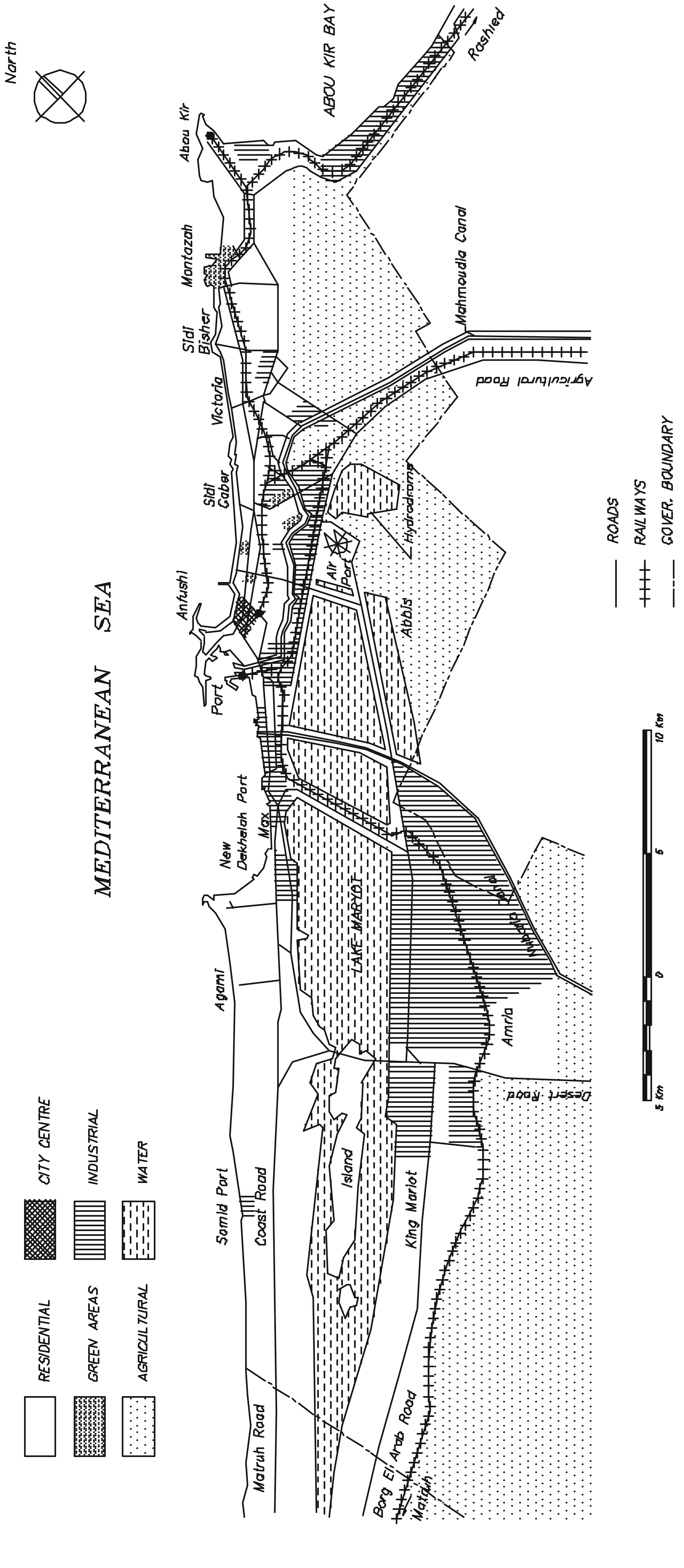



**Figure 5.2:Land Use Plan [35]**

To the east, the section of the city with the most consolidated urban development is bordered by the Mediterranean and Abou Kir railway. The Abou Kir railway (that connects Abou Kir suburb with the city center) also represents a dividing line as far as social structure and land use is concerned. North of the Abou Kir line, the housing infrastructure and services are of a good quality with land and house prices being among the highest in Alexandria. Areas south of the railway, however, are not backed up by adequate basic infrastructures. To the west, the area is strongly tied to the activities of the port, the income levels of the inhabitants are relatively low and house and land values are among the lowest in Alexandria.

In the central area, there are also marked qualitative and functional differences. The characteristic function of a city center (banks, insurance companies, government offices, services, etc.) are concentrated in the kisms of Attarin and Mansheyah, where land and house prices are the highest in the whole of Alexandria. Housing density in the other central areas (The old city: Labban, Gomrok, Moharram Bek and Karmouz) is high and manufacturing and commercial activities are divided into small units. In the old city, 55 to 65% of the housing stock can be considered to be in a dilapidated condition.

Industries are widely scattered through Alexandria's Kisms, with small scale industries inter-mixed with residential areas. The large scale establishments are clustered in few locations. Agglomeration of these industries is very noticeable south and north of the Mahmoudia Canal, near the port, and close to Alexandria/Cairo railroad and highways.

## 5.3 Transportation Situation in Alexandria

### 5.3.1 Roadways

#### 5.3.1.1 Entrance Roadways

Alexandria has 5 main corridors connecting the city with the national road network (Figure 5.3):

- Alexandria/Cairo Agricultural Road, connecting Alexandria with Cairo, runs through the most densely populated areas of the Nile Delta. This road carries the largest traffic flow.
- Alexandria/Cairo Desert Road, a toll highway with excellent geometrical characteristics, providing a direct connection to Cairo.
- Alexandria/Matruh Coastal Road, the only link to Egypt's western region and the new tourist communities.
- Alexandria/Rashied Road, linking Alexandria with both Rosetta (Alexandria neighboring Governorate), and the industrial zones in-between.

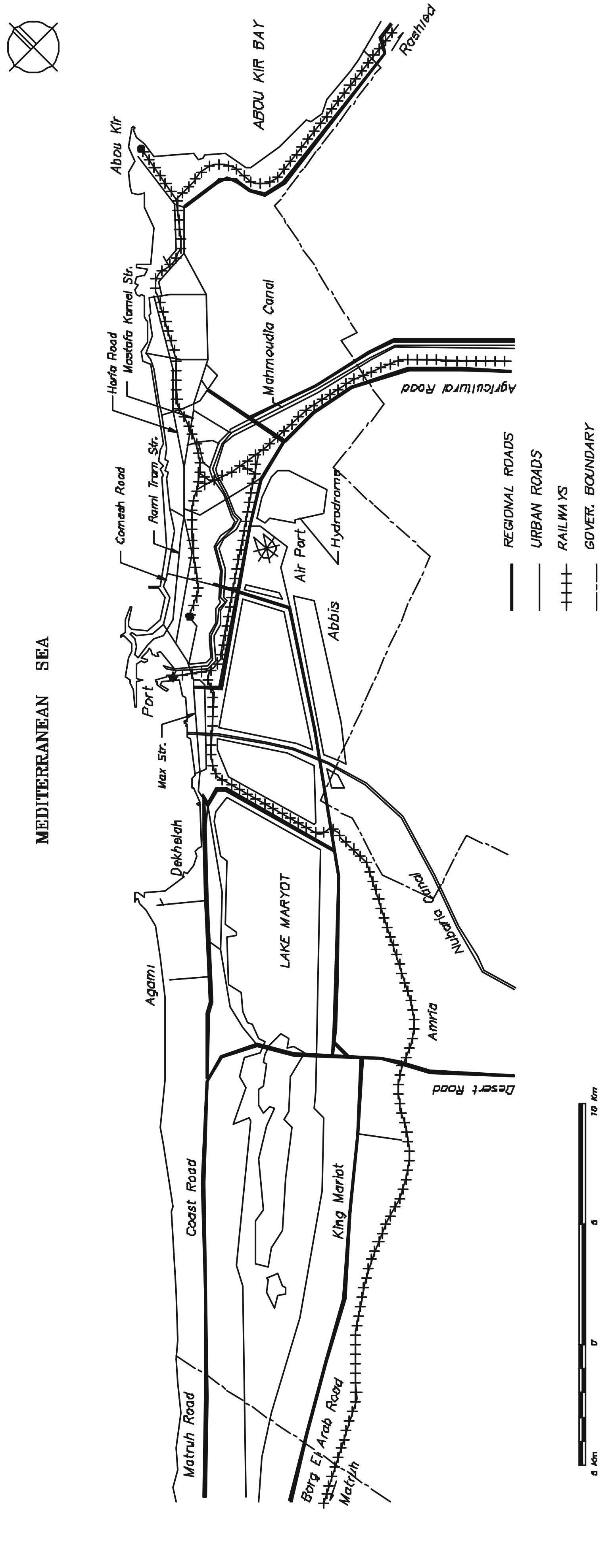



**Figure 5.3: Main Corridors connecting Alexandria with the National Transport Network [35]**

- Alexandria/Kafer El Dawar Road (Mahmoudia Canal Road), serving mainly the cultivated areas between Alexandria and Kafer El Dawar (neighboring Governorate).

The agricultural, the desert, and the coastal roads are connected to each other by an external incomplete ring regional road. It also acts, to a certain extent, as an urban traffic distribution road. Table 5.2 presents the results of a traffic survey carried out in February 1996 as well as in June 1997, by the Transportation Department - Alexandria University, to determine the traffic volumes at the entrance roadways of Alexandria.

**Table 5.2: The Traffic Characteristics at the Entrance roadways of Alexandria**

| Road | Direction | Traffic Volume (pcu/h)* | | Traffic Volume at Peak Hour (pcu/h) | | Percent Truck (%) | |
|---|---|---|---|---|---|---|---|
| | | Feb. | June | Feb. | June | Feb. | June |
| Alexandria/Cairo Agricultural Road | To Alex. | 1626 | 2146 | 1900 | 1967 | 47.4 | 42.1 |
| | From Alex. | 1647 | 1993 | 2401 | 2510 | 47.1 | 43.8 |
| Alexandria/Cairo Desert Road | To Alex. | 1315 | 1907 | 2125 | 2190 | 41.6 | 39.2 |
| | From Alex. | 1028 | 1409 | 2345 | 2411 | 35.3 | 32.8 |
| Alexandria/Matroh Coastal Road | To Alex. | 1206 | 2172 | 1500 | 1710 | 41.1 | 37.9 |
| | From Alex. | 1140 | 1916 | 1661 | 1790 | 38.6 | 36.8 |
| Alexandria/KafrEldwr Mahmodia Road | To Alex. | 446 | 558 | 611 | 680 | 31.6 | 29.9 |
| | From Alex. | 498 | 687 | 633 | 699 | 35.3 | 34.2 |
| Alexandria/Rashid | To Alex. | 484.5 | 929 | 755 | 797 | 35.2 | 33.6 |
| | From Alex. | 539 | 658 | 687 | 714 | 40.0 | 38.2 |

* Passenger Car = 1 pcu, Bus = 2.25 pcu, Microbus = 1.5 pcu, semi-Truck = 1.5 pcu, truck = 2.25 pcu, Truck with trailor = 3.5 pcu

Source: [35]

#### 5.3.1.2 Urban Roadways

The urban road network of Alexandria is, like the city itself, oriented along the East-West axis (Figure 5.4). The grid of the urban road network is constituted by two primary corridors from the East to the city center (Cornesh and Horia Roads) and one corridor from the West to the city center (El Max street). The main link between the eastern and western parts of the city is Seven Girls/El Bab El Achdar streets. Each of which is a one way street (8 - 12 m wide), despite that the City tram runs through in two directions.

The transverse connecting system of the network is very poor. There is only one complete transverse road (Suez Canal Street), which joins the Cornesh with the external regional Road. The secondary road network is extremely limited and, in some cases, even non-existent. The local road networks inside the areas have physical limitations which represent irremovable constraints to future traffic growth. Table 5.3 includes the results of a traffic survey carried out in February 1996, by the Transportation Department - Alexandria University, to define the traffic characteristics on the major roads in Alexandria.

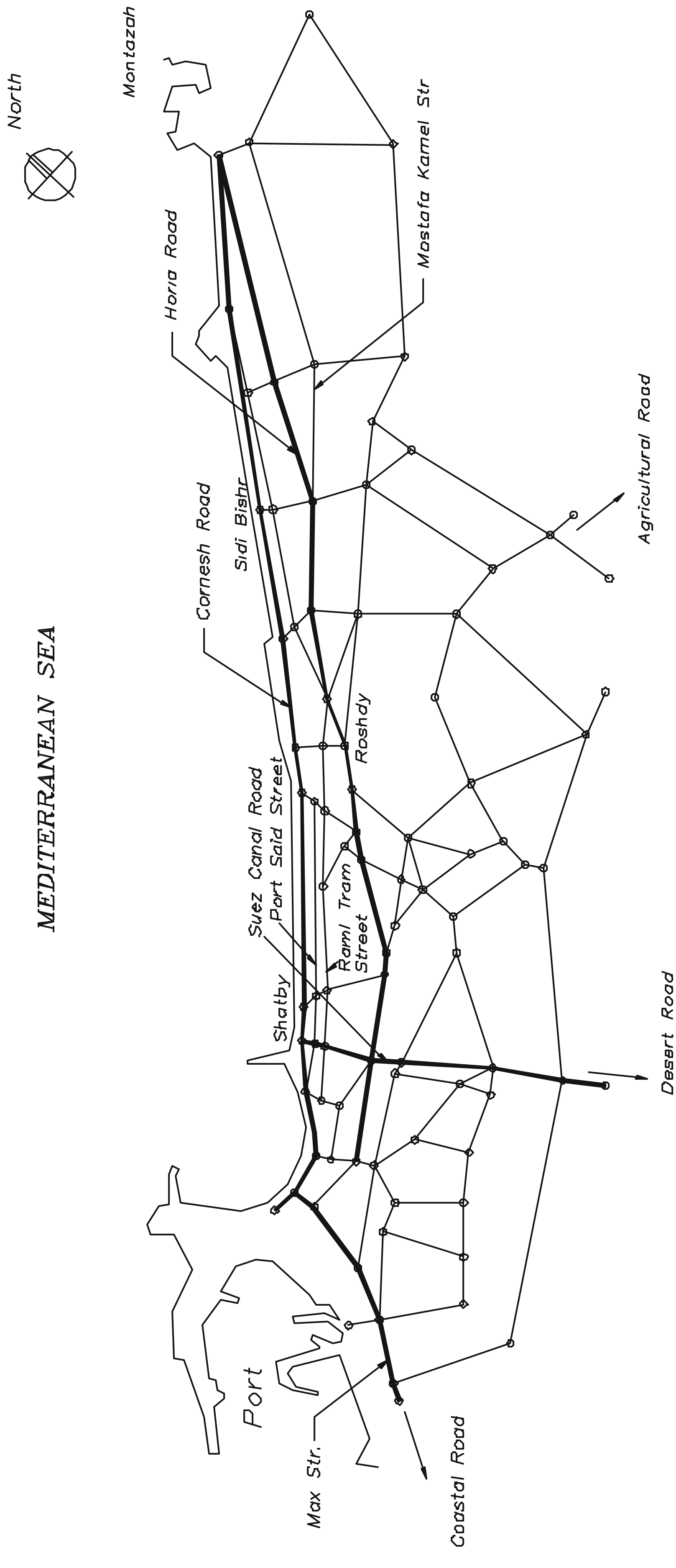



**Figure 5.4: Existing Main Road Network [35]**

**Table 5.3: The Traffic Characteristics at the Major roads of Alexandria**

| Road | Direction | Traffic Volume (pcu/h)* | | Traffic Volume at Peak Hour (pcu/h) | | Road Width (m) | Percent Truck (%) | |
|---|---|---|---|---|---|---|---|---|
| | | Feb. | June | Feb. | June | | Feb. | June |
| **Cornish (Shatby)** | **To City Cent.** | 2887 | 4930 | 6304 | 6712 | 12.0* | 4.7 | 3.9 |
| | **From City Cent.** | 1351 | 2512 | 3227 | 4015 | 6.0 | 5.5 | 4.0 |
| **Cornish (Sidi Bishr)** | **To City Cent.** | 1867 | 3421 | 2877 | 4023 | 5.5 | 7.5 | 6.2 |
| | **From City Cent.** | 1669 | 3020 | 2213 | 4120 | 5.5 | 5.1 | 4.8 |
| **Horia Road (Suezcanal Cross.)** | **To City Cent.** | 3810 | 6090 | 5925 | 7640 | 10.5 | 4.3 | 3.5 |
| | **From City Cent.** | 3673 | 5803 | 4550 | 6232 | 10.5 | 11.7 | 10.4 |
| **Horia Road (Roshdy)** | **To City Cent.** | 1985 | 2954 | 3129 | 4234 | 6.5 | 10.3 | 8.9 |
| | **From City Cent.** | 2032 | 2990 | 2854 | 3727 | 6.5 | 9.5 | 8.3 |
| **Raml Tram (Shatby)** | **To City Cent.** | 1326 | 1657 | 2005 | 2245 | 8.0 | 9.6 | 8.6 |
| | **From City Cent.** | 1314 | 1812 | 1802 | 1967 | 8.0 | 4.6 | 4.2 |
| **Port Said** | **From City Cent.** | 1711 | 2019 | 2484 | 2625 | 10.5 | 9.4 | 8.0 |
| **Mostafa Kamel (Roshdy)** | **To City Cent. From City Cent.** | 1115 | 1393 | 1551 | 1654 | 10.5 | 16.9 | 15.0 |
| **Suez Canal** | **To Elcornish** | 1645 | 2972 | 2665 | 3280 | 12.5 | 20.0 | 17.2 |
| | **From Elcornish** | 1429 | 2536 | 1836 | 2997 | 12.5 | 17.2 | 16.0 |
| **Mex** | **To City Cent.** | 2287 | 4112 | 3110 | 5423 | 9.0 | 21.6 | 19.9 |
| | **From City Cent.** | 2466 | 4717 | 3572 | 5925 | 9.0 | 20.2 | 18.2 |

* One-way street during the peak period (from 7.0 to 11.0)
Source: [35]

The main characteristics of the urban road network in Alexandria can be summarized in the following:

- Insufficient areas for both moving traffic and parking cars.
- No classification of roads into various road classes.
- Excess number of road junctions in short sections.
- Too narrow footpaths.
- Poor condition of road surface.
- Low road level of service (about 5 km/h average speed during the peak period on the network).
- Inadequate traffic signs, signals, road guidance signs, foot crossings, and similar traffic facilities.
- Low traffic safety.

### 5.3.2 Public transport

The public transport in Alexandria is operated by two organizations. The "Public Authority for Passenger Transport" which as a municipal local transport organization operates buses and trams (City tram and Raml tram), and the state railway organization "Egyptian Railway Authority", which operates regional train service (Abou Kir railway). Figure 5.5 shows the public transportation network of Alexandria.

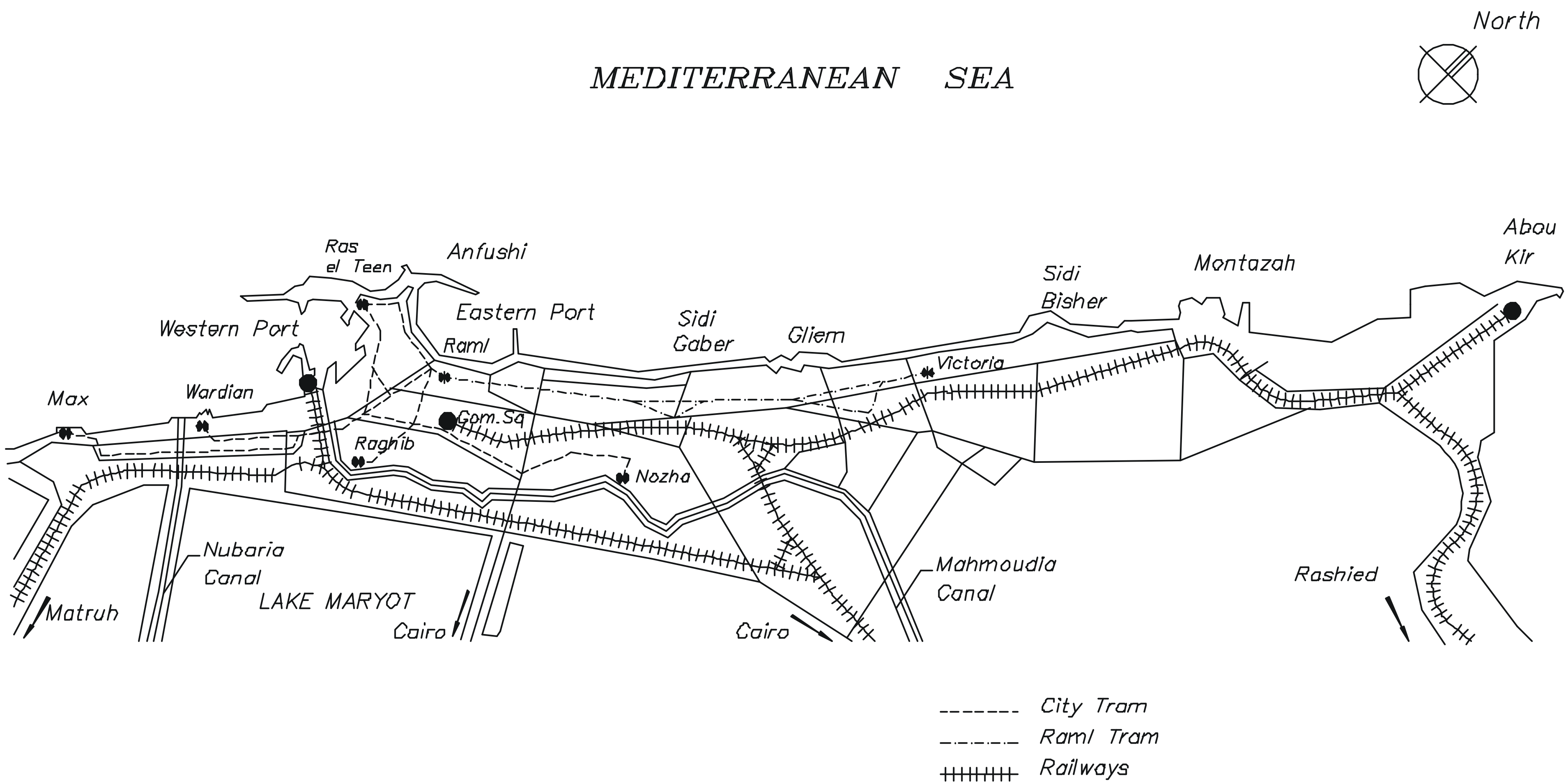



Figure 5.5: Existing Public Transport Network [35]

#### 5.3.2.1 Bus

The bus is the most significant transportation mean in Alexandria. It runs approximately on all the main roads of Alexandria. The bus network includes 87 lines with a total length of almost 1757 km. Some of the lines continue far into the surrounding area, with line lengths of about 65 km. The "Public Authority for Passenger Transport" operates 326 buses and 288 microbuses, with an average headway of about 33 minutes, and average round trip time of 115 minutes.

It must be noted that more than 40% of the nominal number of the buses owned by the "Public Authority for Passenger Transport" are not operated. The reasons for that are: bad conditions of roads, overloading of operating buses, lack of spare parts, and insufficient efficiency of the maintenance facilities. In addition to the public buses, a further 6500 private buses are registered. These are owned by various authorities and used for carrying workers to their workplaces.

#### 5.3.2.2 City Tram

The City tram has no separated track, and runs on its network in the middle of the narrow roads of the old city. 99 articulated carriages are operated on the City tram network, each of which accommodates 150 passengers. In addition, the public transport authority operates also 30 trams with a capacity of 250 passengers each.

The City tram serves the parts of the city to the west, north and south of Orabi Square (16 lines), with about 10 minutes headway and 10.3 km/h commercial speed. Due to the location of the City tram tracks in the middle of the roads, the existing road area serves public and private transport. This intermixture inevitably leads to disruptions to both means of transport. Furthermore, on some locations in the old town, the City tram runs in the two directions on one-way streets.

#### 5.3.2.3 Raml Tram

The Raml tram has its own track, and joins the eastern part of the city with the city center. The track is interrupted by several road junctions, which lead to a reduction of commercial speed (12-15 km/h) with 2.6 min headway. The local conditions permit no possibility for elimination of level crossings.

The existing 36 Raml Tram vehicles were procured between 1976 and 1980, from which only 31 units are in operation to serve 37 stops. Raml tram consists of 3 carriages and can carry 670 passengers (standing room for 574 with 8 persons/m$^2$, seating for 96 persons). In addition, there are 6 double-deck units operating on the same lines.

### 5.3.2.4 Abou Kir Railway

The Abou Kir railway is a two-track system. It starts from the main railway station, serving the connection of the central area with Abou Kir suburb as well as the low-income zones along the southern urban axis. The Abou Kir railway is the fastest mean of public transport in Alexandria. The average traveling speed is about 25 km/h. The route is about 22 km long and has 16 stops. The distance between stops varies between 700 m and 2800 m. Operated on the route are reversible trains. Each train consists of 6 carriages and a diesel locomotive. A total of 13 trains cover the route daily in each direction.

There are 194 trains scheduled per day, 97 cover the route in each direction. In the peak hours the trains run at intervals of 15 to 20 minutes (frequency 3 to 4 train/h/direction), this being extended to about 30 minutes at off-peak hours. The trains have a theoretical capacity of 1500 passengers per train, so that more 130 000 passengers could be carried in each direction. According to the official timetable, the trains cover the total line in 38 minutes, to which must be added the 1 minute stop at each station, producing the total time of 52 minutes. The average speed is 35 km/h. Table 5.4 shows the names and sequences of the Abou Kir railway line, and Figure 5.6 presents the elements of the track alignment.

**Table 5.4: The stations of the Abou Kir railway line**

| Station Name | Distance from Alexandria Station (km) | Distance between Stations (km) |
|---|---|---|
| 1. Alexandria Maser | 0.00 | 0.00 |
| 2. El Hadara | 2.80 | 2.80 |
| 3. Sidi Gaber | 4.83 | 2.03 |
| 4. Zahiriya | 7.38 | 2.55 |
| 5. El Souk | 7.98 | 0.60 |
| 6. Ghebrial | 8.82 | 0.84 |
| 7. El Raml | 9.32 | 0.50 |
| 8. El Nakrashy | 10.20 | 0.70 |
| 9. Sidi Bishr | 11.84 | 1.82 |
| 10. El Asafra | 13.72 | 1.88 |
| 11. El Mandra | 14.75 | 1.03 |
| 12. El Montaza | 15.61 | 0.86 |
| 13. El Islah | 17.51 | 1.90 |
| 14. El Mamoura | 19.13 | 1.62 |
| 15. Tusun Pasha | 21.12 | 1.99 |
| 16. Abou Kir | 22.11 | 0.99 |

The trains circulating on Abou Kir railway line are blocked composition trains. Each set consists of a diesel-electric locomotive at the head of the train and six carriages. The last of these carriages has a driving cab from which the driver can drive the locomotive by remote control. There are a total of 13 sets, 12 in service and one on stand-by. The type of the diesel locomotive is G 22 W/AC constructed in 1980. It has the following characteristics:

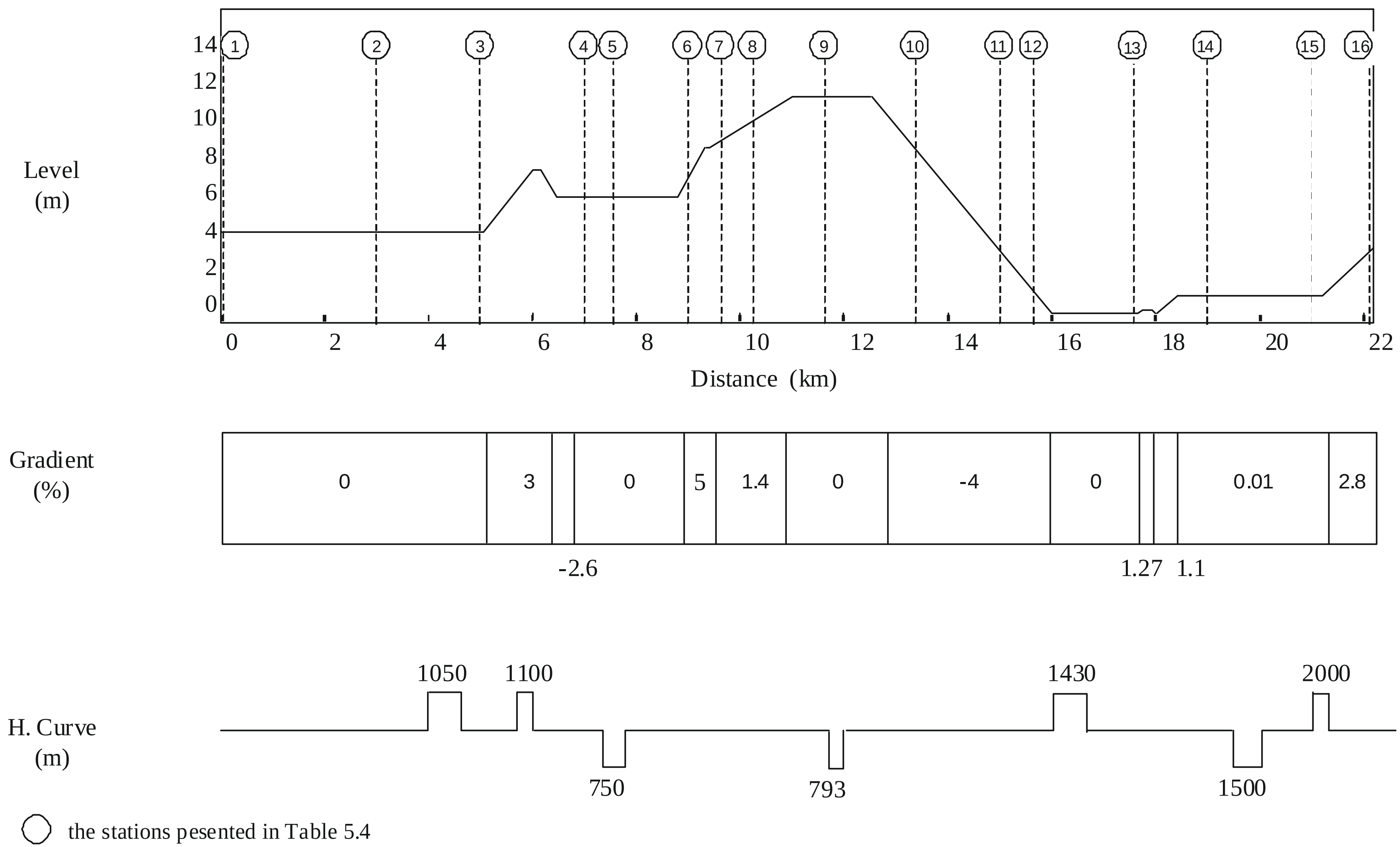



**Figure 5.6: Abou-Kir Railway Line Profile**

- 1500 HP.
- Width 2.743 meter, height 3.816 meter, and length 16.377 meter.
- Total weight of 80 tons.

The carriages were constructed in 1979, they have the following characteristics:

- Width 2.9 meter, Length 22.7 meter, and height 4.32 meter
- Two axle bogies
- Capacity : 2nd class 84 seats and 156 standing
  : 3rd class 108 seats and 172 standing
- Tare weight of 40 tons.

### 5.3.2.5 Conclusion

Generally, the existing public transport system in Alexandria can be characterized as follows:

- there is a shortage in the public transport capacity,
- priorities to public transport over individual transport are inadequate,
- there is no integration between the various components of the public transport system (Bus, Raml tram, City tram and Abou Kir railway), and
- many microbuses are provided by several lines at the same time (no clear organization).

The above-mentioned study proved that both public and individual transport systems cause disruption to each other. This leads to reduce traveling speed, and thus the efficiency of the public transport system is passively affected. Figure 5.7 presents the numbers of the public transport passengers between 1990 and 1996. It can be noticed that the total number of passengers had reached its maximum in 1992/1993 and its minimum in 1995/1996.

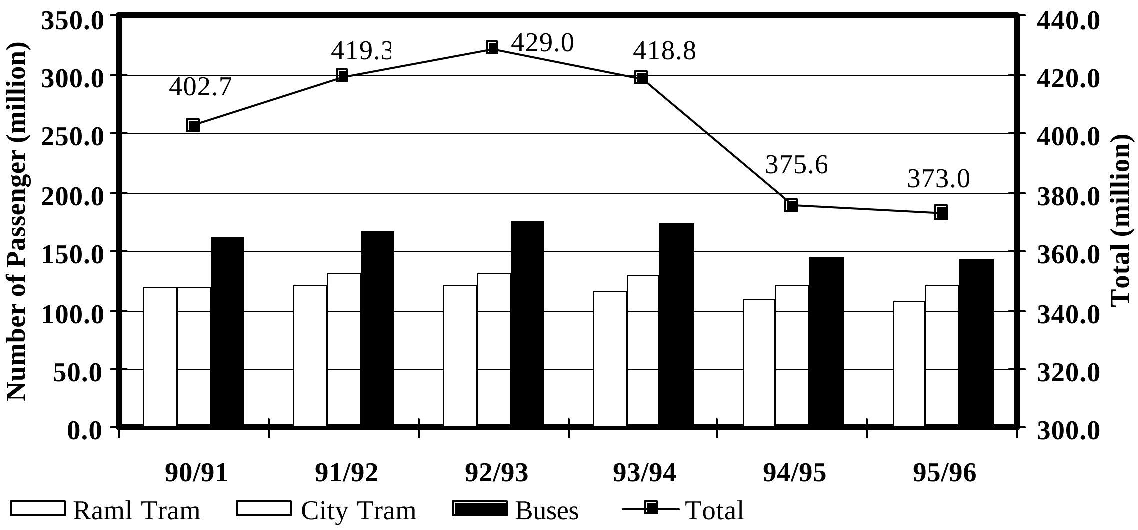



**Figure 5.7: Distribution of Public Transport Passengers between 1990 and 1996 [35]**

### 5.3.3 The Motorization in Alexandria

Figure 5.8 shows the development in car-ownership of the different vehicle types registered in Alexandria between 1990 and 1996, as well as the availability of the other various vehicle types per 1000 inhabitants. It should be noted that:

- The car-ownership has been increased from 45 to 48.5 veh./1000 inh. due to the increase of cars from 135 000 in 1988 to 175 000 in 1995, as well as the increase in the number of population from 3.0 to 3.6 Mil. during the same period.
- The availability of taxis increased from 4.4 veh./1000 inh. to 6.3 veh./1000 inh. during this period because of the great increase in the number of taxis from 13 300 to 22 700.
- The availability of microbus increased from 3.5 veh./1000 inh. to 3.7 veh./1000 inh. through the same period due to the increase of the number of microbus from 10500 to 13400.
- The availability of private buses increased from 1.14 veh./1000 inh. to 1.82 veh./1000 inh. and the number of vehicles increased from 3 330 to 6 540.

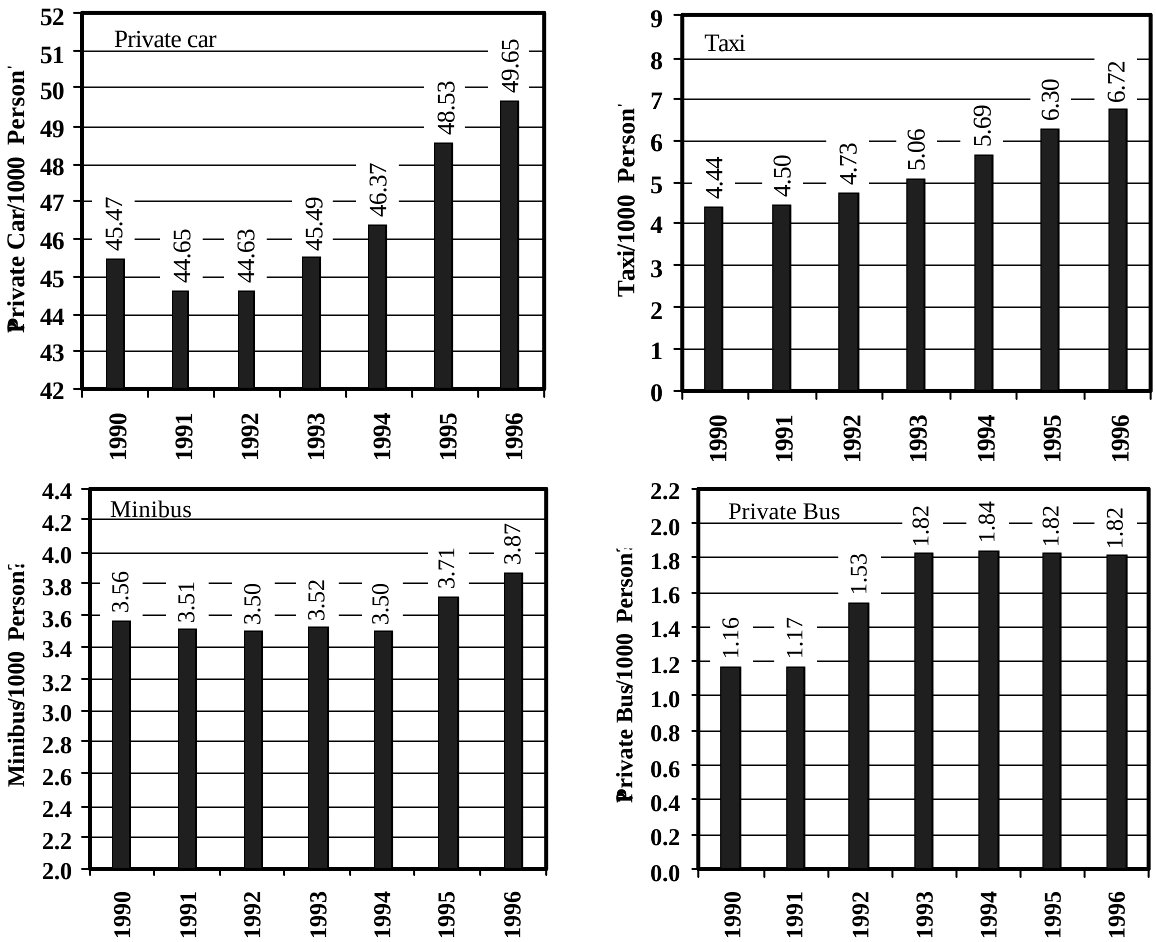



**Figure 5.8: Development of Ownership of Different Types of Vehicle, Alexandria 1990/1996 (Vehicle/1000 Person) [35]**

Figure 5.9 shows the approximate distribution of private car according to the age in years 1985, 1990, and 1996. As can be seen, there are significant shares of old vehicles in the Alexandria fleet. On the other hand, the share of new vehicles has been rapidly increased from 1985 until 1996 due to the increase in the level of income as well as the continually reduction in the new vehicle price.

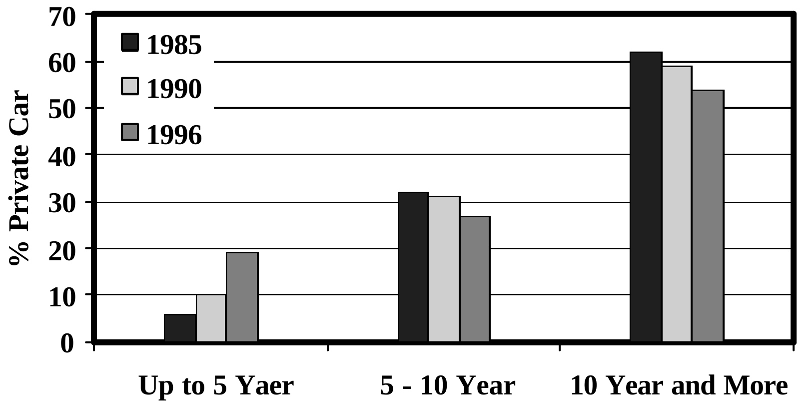



**Figure 5.9: Private Car Distribution According to the Age, Alexandria 1985, 1990, and 1996**

### 5.3.4 Travel Behavior

#### 5.3.4.1 Modal Split

Based on the study "Alexandria Bus Route planning- 1996" [62], the average number of the daily trips carried out in Alexandria was about 2 662 400, distributed as follows (Figure 5.10):

| | | | | | |
|---|---|---|---|---|---|
| - | Public Bus | 19.6 % | - | City Tram | 14.8 % |
| - | Raml Tram | 13.5 % | - | Railways | 4.80 % |
| - | Private Buses | 10.6 % | - | Taxis | 6.50 % |
| - | Microbus | 13.2 % | - | Private Car | 17.0 % |

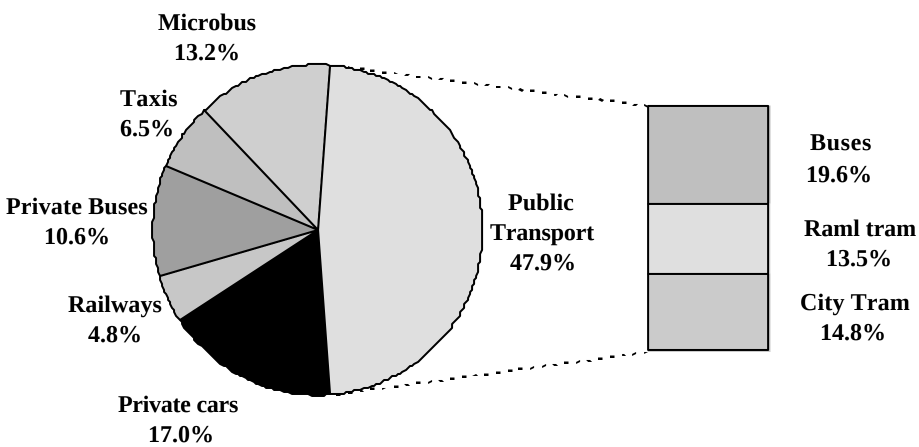



**Figure 5.10: Modal Split, Alexandria 1996**

### 5.3.4.2 Distribution of Travel Demand by the Period of a Day

In Alexandria, the morning peak demand is concentrated between 7 and 9 o'clock, while the afternoon peak is more spread out. There is semi- peak at 13 o'clock, and then between 14 and 16 o'clock. Figure 5.11 illustrates the distribution of the demand according to the period of the day. The purpose of the morning peak traffic is to go to work or to school (essential trips), while the reason of the afternoon peak is return home. Unessential trips tend to be in the off-peak periods.

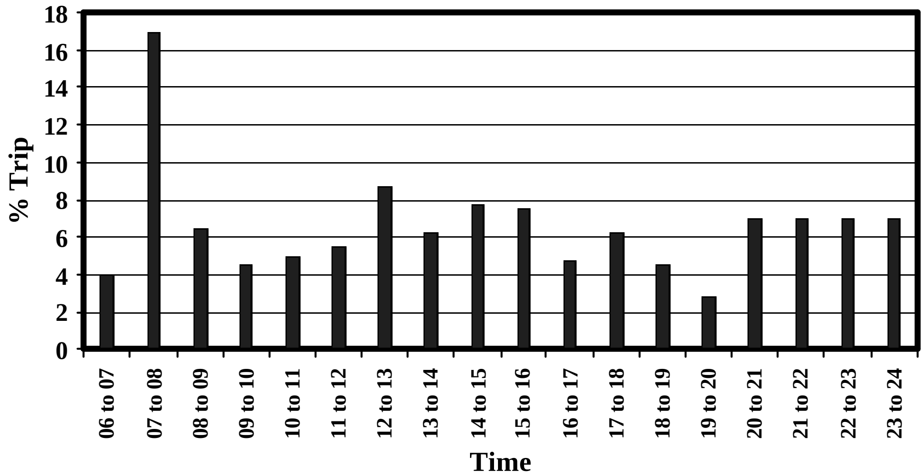



**Figure 5.11: Distribution of the Demand according to the Hours of the Day [35]**

### 5.3.4.3 Trip Purpose

If we leave aside trips for the reason "return home", which account for about 50 % of the whole trips, the most trips are made to go to work (20.9 %) and to go to school (16.9 %); as shown in Figure 5.12. This means that more than 75 % of the trips carried out in Alexandria (back home excluded) can be considered essential trips (work and education). This means also, that due to traffic problems citizens of Alexandria abandon some inessential trips; such as recreation and private affairs.

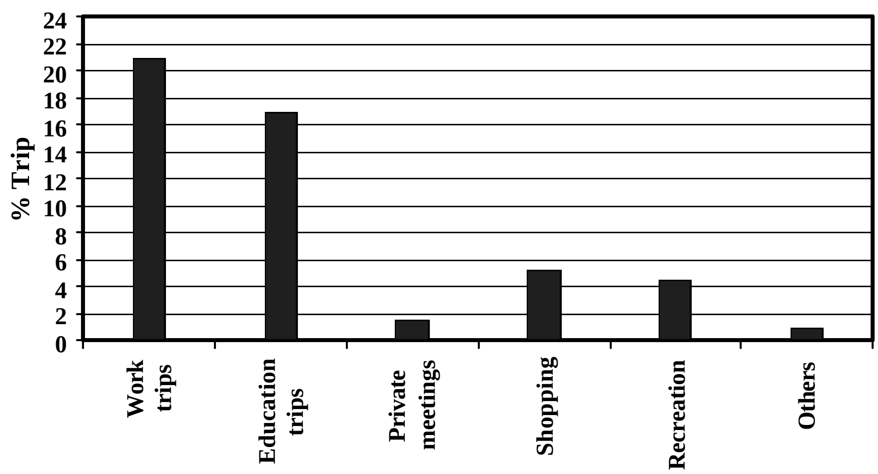



**Figure 5.12: Distribution of the Daily Trips by Purpose [35]**

# CHAPTER 6
# THE PRESENT SITUATION OF ENERGY CONSUMPTION IN THE TRANSPORT SECTOR IN ALEXANDRIA

## 6.1 General

The transport sector in Egypt accounts for about 29 percent of total the final energy consumption. It is almost totally dependent on petroleum derived fuels and nearly about 43 percent of the nation's use of petroleum fuels is taken by transport activity. Thus, energy demand for transport in Egypt has a major bearing on the energy market.

In addition, the transport system in the urban areas consumes about 52 percent of total transport energy consumption in Egypt. Alexandria as the second largest city in Egypt, maintains a dominant share. The main objectives of this chapter are (a) to illustrate the Egyptian energy sector and the share of the transportation to the final energy consumption, (b) to calculate the transport energy consumption and emissions in Alexandria, as a case study in the base year 1996, in order to calibrate the models developed in chapter 4, and (c) to develop a comparison between Alexandria city, Egypt, and Hannover city, Germany, for the aim of transferring technologies, knowledge and experiences.

## 6.2 Overview of the Egyptian Energy Sector

According to the official published statistics, the total prime energy (crude oil, condenses, LPG, natural gas, hydro, and coal) production in the year 1996 was about 58.5 Mtoe. Between 1973 and 1996, the production increased by an annual growth rate of about 2 percent. Crude oil provided the largest share of energy supply, in 1996 about 71 percent of Egypt primary energy supplies was oil.

Transport sector is considered as one of the largest energy consuming sectors. The final energy consumed by the transport sector (including the fuel consumption at ports and airports) in the year 1996 was about 7.6 Mtoe with a share of about 29 percent of total final energy consumption. Thus, the transport sector in Egypt is the second largest energy consumer. Figure 6.1 shows the energy balance in Egypt, 1996.

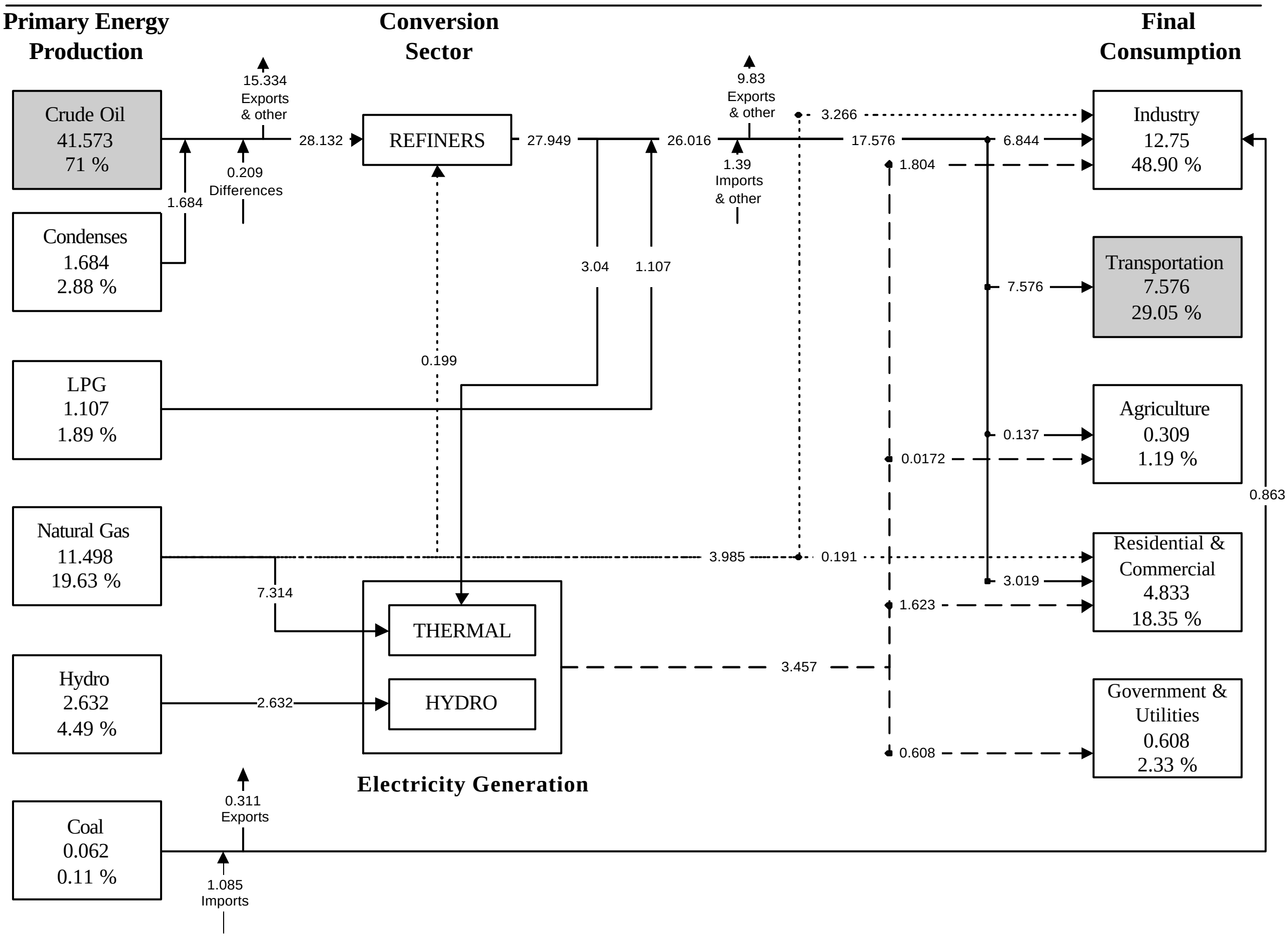



**Figure 6.1: Egypt Energy Balance in Mtoe, 1996/1997 [63]**

The transport sector is the largest oil consumer. In 1996, the transport sector comprised about 43 percent of the use of oil products (among the other economic sections). Gas oil is considered as the largest fuel consumed by transport sector, representing about 2.5 Mtoe.

Road transport maintains a dominant share of transportation energy use. In 1996, road transport is responsible for about 51 percent of total transportation energy consumption. Table 6.1 illustrates the distribution of energy consumption according to fuel types and transport modes in Egypt 1996.

**Table 6.1: Distribution of Fuel consumption according to Fuel Type and Transport Modes in thousand tons, Egypt 1996**

| Mode/Fuel Type | Gasoline | Gas oil | Fuel oil | Jet-Fuel | Total |
|---|---|---|---|---|---|
| **Roads** | 2024 | 1874 | - | - | 3898 |
| **Railways** | - | 245 | - | - | 245 |
| **Waterways** | - | 81 | - | - | 81 |
| **Ports** | - | 324 | 2164 | - | 2488 |
| **Airports** | - | - | - | 864 | 864 |
| **Total** | 2024 | 2524 | 2164 | 864 | 7576 |

Source: [47]

Alexandria as the second largest city in Egypt, maintains a dominant share of national transportation energy use. In 1996, the transportation sector in Alexandria consumed about 68000 ton Gasoline and 49736 ton Gas oil. Table 6.2 illustrates the distribution of energy consumption according to fuel types and transport modes in Alexandria 1996.

**Table 6.2: Distribution of Fuel consumption according to Fuel Type and Transport Modes**

| Mode | Consumption | | | |
|---|---|---|---|---|
| | **Gasoline** *(1000 ton)* | **Gas Oil** *(1000 ton)* | **Electricity** *(1000 kWh)* | **Total** *(Tj)* |
| **Private Car** | 49.133 | -- | -- | 2073 |
| **Taxi** | 18.989 | -- | -- | 801 |
| **Public Bus** | -- | 19.179 | -- | 823 |
| **Private Bus** | -- | 6.460 | -- | 277 |
| **Microbus** | -- | 14.900 | -- | 639 |
| **Abou Kir** | -- | 9.196 | -- | 395 |
| **Raml Tram** | -- | -- | 19794 | 196 |
| **City Tram** | -- | -- | 18742 | 186 |
| **Total** | 68.121 | 49.736 | 38536 | 5390 |

Data Source: [45]

## 6.3 Calculation of the Transport Energy Consumption and Emissions in Alexandria, in the Base Year 1996

Table 6.3 summarizes mobile source sectors, modes, classes, fuel types and emission species that considered in the calculation of the energy consumption and emissions in Alexandria. Mobile sources included are road and rail transport. Road transport sector is divided into five modes private cars, taxi, public bus, private bus, and small buses (microbus). Private cars are further classified by age of the vehicle. They are split into three vehicle age classes (>10 years old, 5-10 years old, and < 5 years old). Rail transport sector contains three modes Abou Kir railway line, City tram, and Raml tram. The fuel types are gasoline, gas oil and electricity. The emission types considered are $CO_2$, $CH_4$, and $NO_2$.

**Table 6.3: Mobile Source Sectors, Modes, Classes, Fuel Types, and Emissions**

| Mobile Source Sectors | Modes | Classes | Fuel Types | Emissions |
|---|---|---|---|---|
| **Road Transport** | **Private Cars**<br><br><br>**Taxi**<br>**Microbus**<br>**Private Buses**<br>**Public Buses** | >10 years old<br>5-10 years old<br><5 years old | Gasoline<br>Gas Oil | $CO_2$<br>$CH_4$<br>$NO_2$ |
| **Rail Transport** | **Abou Kir Railway Line**<br>**City Tram**<br>**Raml Tram** | | Gas Oil<br>Electricity | $CO_2$<br>$CH_4$<br>$NO_2$ |

### 6.3.1 Road Transport

#### 6.3.1.1 Energy Consumption Rates

The determination of the energy consumption rates for different road transport modes in Alexandria is based on data collected from different sources [1,47,64,65] and on some assumptions. Table 6.4 presents the fuel consumption rates (FCR) for the private car according to the distribution of age classes as well as the calculated composite fuel consumption rate (each class's fuel consumption rate is multiplied times its relative prevalence in the fleet). This composite fuel consumption rate represents the full fleet of the private cars.

**Table 6.4: Fuel Consumption Rates (FCR) of Private Car in 1996 (Gasoline)**

| Mode | Class | FCR (l/100km) | Prevalence (%) | Composite FCR (l/100km) |
|---|---|---|---|---|
| Private Car | **Up to 5 Years** | 10.3 | 19 | 11.87 |
| | **5 – 10 Years** | 11.3 | 27 | |
| | **10 Years and More** | 12.7 | 54 | |

Table 6.5 shows the fuel consumption rates for different road transport modes in Alexandria. These rates are found to be suitable at the average speeds listed in the table.

**Table 6.5: Fuel Consumption Rates for different Transport Modes in Alexandria**

| Mode | Average Speed (km/h) | FCR by Fuel Type (l/100km) | |
|---|---|---|---|
| | | Gasoline | Gas Oil |
| **Private Car** | **30-40** | **11.87** | **-** |
| **Taxi** | **30-40** | **15.2** | **-** |
| **Microbus** | **30-40** | **-** | **20.5** |
| **Public Bus** | **20-30** | **-** | **48.9** |
| **Private Bus** | **20-30** | **-** | **41.5** |

In order to develop the previous fuel consumption rates at different average speeds, the Swiss/German emissions model "Handbuch der Emissionsfaktoren des Straßenverkehrs 1999" [21] has been studied within the framework of this study. It provides fuel consumption factors for all vehicle types at different urban driving patterns (i.e. different average speeds in urban areas). When these factors are displayed as a function of the average speed, the energy consumption factors tend for the most part to fall on a reasonably smooth curve. It is therefore possible to generalize the Swiss/German energy consumption factors as continuous functions depending on the average vehicle speed.

The characteristic shapes of these curves have been studied and thought that they are constant somewhat for each vehicle type (i.e. P.C., L.D.V., and H.D.V.). Thus, the differences in the fuel consumption due to the changes in the average speeds are always constant for every vehicle type. Figure 6.2 presents the calculated differences in the fuel consumption due to the changes in the average speeds according to the Swiss/German emissions model.

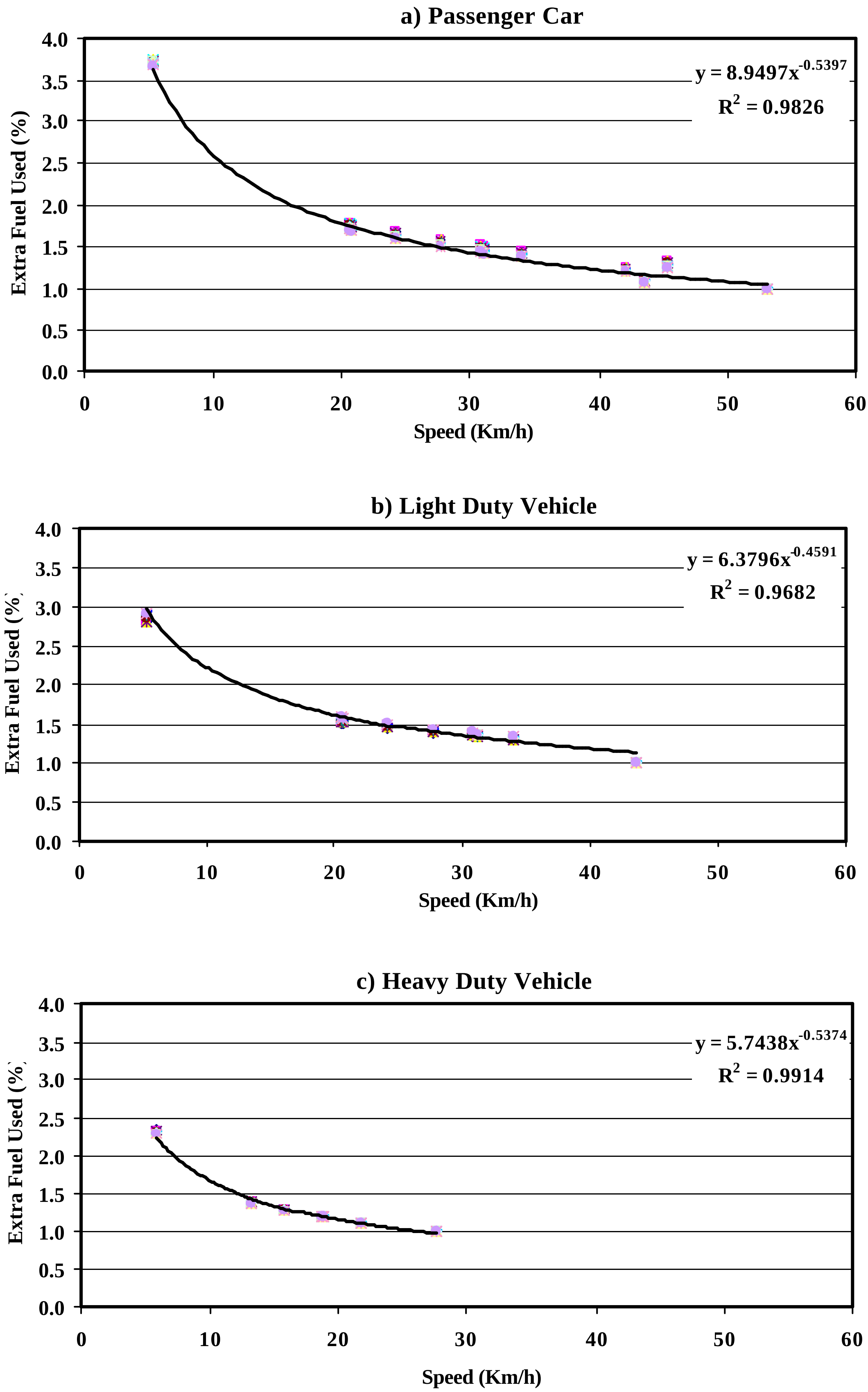



**Figure 6.2: Extra Fuel Used due to Average Speed Distribution for model year 1985 until 1999 (Source Data [21])**

These differences are used with Alexandria fuel consumption rates, listed in Table 6.5, in order to develop fuel consumption rates at different average speeds for Alexandria road transport sector.

#### 6.3.1.2 Conversion Factors and Specific Emission Rates

Based on data collected about the quality of different types of fuel used in Egypt, Table 6.6-a and 6.6-b present the conversion factors and the emission rates for $CO_2$, $CH_4$, and $N_2O$ according to fuel type.

**Table 6.6-a: Conversion Factors**

| Fuel | Specific Gravity | Tj / 1000 t | Mj / Liter |
|---|---|---|---|
| **Gasoline** | 0.732 | 42.2 | 30.89 |
| **Gas Oil** | 0.840 | 42.9 | 36.04 |
| **Natural Gas** | | 42.5 | - |
| **Electricity generation from fuel oil and natural gas:** | | | |
| **- 224 – 235 gram fuel / kWh (traditional power stations)** | | | |
| **- 196 gram fuel / kWh (new power stations)** | | | |

Source: [45]

**Table 6.6-b: Specific Emission Rates according to Fuel Type in Egypt**

| Fuel | g $CO_2$/ g Fuel | kt $CO_2$/ PJ | G $CH_4$/ kg Fuel | t $CH_4$/ PJ | g $N_2O$/ kg Fuel | t $N_2O$/ PJ |
|---|---|---|---|---|---|---|
| **Gasoline** | 3.172 | 75.166 | 4.11 | 97.393 | 0.928 | 21.990 |
| **Gas Oil / Diesel** | 3.188 | 74.312 | | | 2.190 | 51.049 |
| **- Road < 3.5 t** | | | 0.21 | 4.895 | | |
| **- Road > 3.5 t** | | | 0.31 | 7.226 | | |
| **- Railways** | | | 0.36 | 8.392 | | |
| **- Natural Gas** | 2.380 | 56.000 | 0.013 | 0.306 | 0.085 | 2.000 |

Source: [45]

#### 6.3.1.3 Activity Calculation

For the aim of activity calculation for Alexandria road transport modes, a computer-aided transport planning, called VISUM [66], has been used. It is based on the man/machine dialogue concept for planning of complex urban road networks. It supports planners to analyze and to evaluate network modifications. After the evaluation, the planner can modify the designs and thereby moves toward other candidate alternatives that come closest to the planning objectives [24].

VISUM permits the following applications [66]:

- Interactive network creation and modification.
- Assignment of forecast travel demand on road networks.
- Determination of the different traffic characteristics, such as travel times, and average speeds.
- Calculation of environmental impacts (such as pollutant emissions).

The base network should firstly coded as well as the travel demand between the different traffic zones (O-D matrix, in vehicles per hour) should inputted to the computer. Every intersection of the network where roads diverge, or cross is developed as a node with a coordinate. A link exists between two nodes and indicated by the numbers of a pair of nodes, and illustrated by its characteristics (e.g. road capacity).

The road network entered to the VISUM is an abstract version of the road system in Alexandria in 1996, aggregated to 125 nodes and 360 real links. The road characteristics information (e.g. average speed and turning relations) is also entered.

In addition, the travel demand (O/D matrix in the peak hour for each transport mode, 1996), which is distributed among the 14 global zones of Alexandria, is subjected to a successive multi equilibrium assignment. The resulted traffic volumes should be compared with those from actual traffic counting [24].

The calibration of the road characteristics is carried out based on the trial and error procedure. If the comparisons are not in close agreement, adjustments should be made to the initial parameters by multiplying the used values by the ratio of the average observed to predicted flows [24].

Thus, the calibration process is repeated until satisfactory results are achieved (in the case study of the Alexandria, the VISUM program resulted a maximum difference of 15 percent between the predicted and observed flows).

#### 6.3.1.4 Total Energy Consumption and related Emission

Using the output data from the assignment (activity and average speeds) as an input data in the TraEnergy program, explained in Chapter 4, the total energy consumption and emission from road transport are calculated in the base year 1996 for Alexandria. ANNEX II presents an example for the input and output data sheets from TraEnergy program (Figures A and B). The total energy consumption needed for road transport modes in Alexandria was 4.532 Pj in the year 1996 (Table 6.7).

**Table 6.7: Total Road Energy Consumption and Emission by Fuel Type and Transport Mode, 1996**

| Mode | Energy Consumption | | | Emission | | |
|---|---|---|---|---|---|---|
| | Gasoline *(Mill. Lit.)* | Gas Oil *(Mill. Lit.)* | Total *(Tj)* | $CO_2$ *(kilo-ton)* | $CH_4$ *(ton)* | $NO_2$ *(ton)* |
| **Private Car** | 64.685 | -- | 1993 | 150.192 | 194.606 | 43.940 |
| **Taxi** | 26.124 | -- | 805 | 60.657 | 78.595 | 17.746 |
| **Public Bus** | -- | 22.197 | 809 | 60.149 | 5.849 | 41.320 |
| **Private Bus** | -- | 7.024 | 256 | 19.034 | 1.851 | 13.075 |
| **Microbus** | -- | 18.356 | 669 | 49.741 | 4.837 | 34.170 |
| **Total** | 90.809 | 47.577 | 4532 | 339.773 | 285.738 | 150.251 |

### 6.3.2 Rail Transport

#### 6.3.2.1 Specific Power Consumption

For the aim of developing specific power consumption (kWh/trip) for rail transport modes in Alexandria, a computer-aided interactive system called DYNAMIS [67], established at the Institute for Transportation, Railways Construction and Operation of Hannover University (IVE), has been used. This system is the result of the extensive work of different specialists in the fields of railway engineering, mathematics, and computer science.

DYNAMIS is used officially for timetable construction and the calculation of energy consumption by the Austrian Railways (ÖBB) and the Hamburg metropolitan Company (HHA). DYNAMIS is also installed at the German Railway Company (DEG) and for research at several universities.

DYNAMIS does work on a modern UNIX-Workstation using the modern graphical X-Window-System. It has already been used in a large number of operational investigations. To facilitate the operation, different terminals are connected with the main station, each of which includes monitors, keyboard and mouse. DYNAMIS is written in the computer language FORTRAN and C++, and it is possible to transfer it to any other workstation which has the same hardware system.

By the application of DYNAMIS, the following technical fields can be analyzed:

- Determination of power consumption.
- Calculation of running times for different operating programs.
- Determination of signal positions, safety sections behind signals and other safety installations.
- Determination of movement characteristics parameters.

The track data can be imported by the interactive graphic system SIMU. The graph elements are specified by data which describes curves, grades, elevations, and station locations. In addition, different resistance functions can either be selected or defined. The characteristic curves of the traction vehicles, such as traction-force/brake-force-velocity-diagrams, are imported and visualized.

ANNEX III presents the output data and graphics from DYNAMIS for the Abou Kir railway line (Figures A and B). Table 6.8 presents the specific power consumption for the different rail systems in Alexandria. It should be noted that because of the absence of the data about Raml tram and City tram, the specific power consumption for these two systems are calculated based on data collected from the statistics of different sources [47,64,65].

**Table 6.8: Specific Power Consumption for the different Rail system in Alexandria**

| Rail transport Mode | | Specific Power Consumption |
|---|---|---|
| **Abou Kir Railway Line *** | **from Abou Kir station to Alexandria station** | 95.7 (kWh/trip) * |
| | **from Alexandria station to Abou Kir station** | 109.4 (kWh/trip) * |
| **Raml Tram** | | 8.7 (kWh/km) |
| **City Tram** | | 8.4 (kWh/km) |

* Output results from DYNAMIS

### 6.3.2.2 Total Energy Consumption and Emissions

According to the previous specific power consumption, the energy consumption and emission for the rail transport modes are calculated (Table 6.9). The total energy consumption needed for rail transport modes in Alexandria was 0.778 Pj in the year 1996.

**Table 6.9: Total Road Energy Consumption and Emission by Fuel Type and Transport Mode, 1996**

| Mode | Energy Consumption | | | Emission | | |
|---|---|---|---|---|---|---|
| | **Gas Oil** *(Mill. Lit.)* | **Electricity** *(1000 kWh)* | **Total** *(Tj)* | **$CO_2$** *(kilo-ton)* | **$CH_4$** *(ton)* | **$NO_2$** *(ton)* |
| **Abou Kir** | 10.819 | -- | 396 | 29.317 | 2.851 | 20.140 |
| **Raml Tram** | -- | 18742 | 186 | 13.925 | 1.521 | 9.451 |
| **City Tram** | -- | 19794 | 196 | 14.706 | 1.607 | 9.981 |
| **Total** | 10.819 | 38536 | 778 | 57.948 | 5.979 | 39.572 |

### 6.3.3 Calibration of the Model

The purpose of the energy consumption and emissions calculation, in the base year 1996, is to calibrate the accruing of the developed framework. Thus, the resulted energy consumption values are compared with those from [61]. Table 6.10 presents the comparison and shows that the maximum difference is found to be 4.7 percent between the results.

values are compared with those from [61]. Table 6.10 presents the comparison and shows that the maximum difference is found to be 4.7 percent between the results.

**Table 6.10: Comparison between the Calculated and Statistic Values for the Energy Consumption for different Transport Modes,** ***Alexandria 1996***

| Transport Mode | Energy Consumption (Tj) | | Difference (%) |
|---|---|---|---|
| | Statistic [61] | Calculated | |
| **Private Car** | 2073 | 1993 | 3.9 |
| **Taxi** | 801 | 805 | -0.5 |
| **Public Bus** | 823 | 809 | 1.7 |
| **Private Bus** | 277 | 265 | 4.3 |
| **Microbus** | 639 | 669 | -4.7 |
| **Abou Kir** | 395 | 396 | -0.3 |
| **Raml Tram** | 196 | 196 | 0.0 |
| **City Tram** | 186 | 186 | 0.0 |
| **Total** | 5390 | 5319 | 1.5 |

## 6.4 Comparison between Alexandria and Hannover

Between one country and the next, there are many differences in the set of ingredients that make up transport energy consumption trends. Comparison between countries, or cities, require consideration of the factors leading to these differences in order to understand how energy use for transport has evolved and to determine where policies can be most effective.

Table 6.11 presents a simple comparison between Alexandria City and Hannover City. The aim of this comparison is to transfer experience, policies, and technologies. The integration view allows better understanding of how the various components have shaped and will shape energy developments in the both cities.

As can be shown in the table, the energy consumption per pass-km for all modes in Alexandria is lower than in Hannover because of the higher occupancy for all modes in Alexandria. Lower energy intensities of vehicles (high percent of new vehicles and technologies) and higher average speeds in Hannover reduce the energy consumption per pass-km, but falling occupancy offset this restraint. As an example, the energy consumption per passenger-km for cars in Hannover is lower than in Alexandria (1.09 Mj/Pass-km) using the same occupancy for cars in Alexandria.

Public transport system in Alexandria, as shown in the Table, is an efficient mode because of the high utilization rates (more than 100 percent in the peak periods). This means that the existing public transport in Alexandria should be upgraded and developed to win more users; i.e. pull people from private cars and push them to the public transport systems.

**Table 6.11: Comparison between Alexandria and Hannover**

| Factor | Alexandria | | Hannover | |
|---|---|---|---|---|
| **Population (Mil.)** | 3.328 | | 1.15 | |
| **Mobility (trips/ (inh.*day))** | 0.8 | | 2.9 | |
| **Trips (Mil.)** | 971.78 | | 1218 | |
| **Activity (Mil. Pass-km)** | Trams | 2357 | Trams | 518 |
| | Buses | 4983 | Buses | 423 |
| | Railway | 1032 | Railway | 692 |
| | Cars | 1827 | Cars | 6765 |
| **Average Occupancy** | Trams | 527 | Trams | 94 |
| | Buses | 65 | Buses | 24.4 |
| | Railway | 533 | Railway | 128 |
| | Cars | 2.5 | Cars | 1.41 |
| **Traffic Condition** | Unstable | | Stable | |
| **Public Transport Utilization (Actual Pass./Capacity)** | Trams | 85.6 % | Trams | 23.0 % |
| | Buses | 68.0 % | Buses | 17.0 % |
| | Railway | 90.0 % | Railway | 29.0 % |
| **Mj/Pass-km** | Trams | 0.16 | Trams | 1.54 |
| | Buses | 0.35 | Buses | 0.95 |
| | Railway | 0.38 | Railway | 1.45 |
| | Cars | 1.53 | Cars | 1.94* |
| **Energy Consumption (Tj)** | Trams | 382 | Trams | 800 |
| | Buses | 1743 | Buses | 400 |
| | Railway | 396 | Railway | 1000 |
| | Cars | 2798 | Cars | 13121 |
| | Total | 5319 | Total | 15321 |
| **Fuel Price (Gasoline) (DM)** | 0.6 | | 2 | |
| **Emissions (1000 ton emissions)** | $CO_2$ | 403,0 | $CO_2$ | 1193 |
| | $CH_4$ | 0.298 | $CH_4$ | 0.632 |
| | $NO_2$ | 0.192 | $NO_2$ | 0.522 |

* (1.09 for occupancy 2.5)
Data Source: [61] (for Alexandria)
Data Source: [68] (for Hannover)

In spite of the population in Hannover about one third the population in Alexandria, the energy consumption and the corresponding emissions in Hannover are about three times more than those in Alexandria. This may be a result of the intensive use of the private cars in Hannover as well as the high occupancy of vehicles in Alexandria.

# CHAPTER 7
# ENERGY CONSUMPTION AND SUSTAINABLE TRANSPORT IN ALEXANDRIA

## 7.1 General

Everyday the citizens in Alexandria are subject to the depressing experiences of the rush hours: traffic jams, pollution, stressed nerves, frequent accidents, as well as wasted time and fuel. In addition, the only transport energy source in Egypt is crude oil. According to best estimates, there are currently 42.9 Mtoe, enough to continue about 11 years at present consumption rates. Thus the existing transport and energy systems in Alexandria are not sustainable and need measures to be taken at a number of levels in order to mitigate the negative effects of transport and to reduce the increasing dependence on the crude oil as a main transportation energy source in Egypt.

In this chapter, a new transportation master plan for Alexandria based on the sustainable development concept of mobility and energy consumption is prepared. Then, different possible scenarios (combination of different measures) for the future transport system in Alexandria based on this plan are prepared and evaluated.

## 7.2 Towards Sustainable Development of Mobility and Energy

The preparation of a new transportation plan for Alexandria based on the sustainable development concept of mobility, should have firstly an integrated land use/transportation planning in order to reduce the travel demand and to stop the random development of the city. After that, attempts must be concentrated on creating a large-scale rapid transit network which can successively be developed step by step to become a complete exclusive right-of-way metro system in the future. Attempts should be also concentrated on charging of high fuel price in order to discourage the use of private car as well as to use the revenue for investment in infrastructure of public transport systems. Thus, the aim is to find an alternative for the private car trips to ease the load on the overloaded road network (modal shift). Lastly, traffic management measures, permit a good chance for smoothing traffic on the road network. The objectives of these measures are to improve the usefulness of the existing traffic facilities in a convenient, safe, economic and environment way [24].

Moreover and for the aim of preparing sustainable energy consumption plan, the intensive use of Compact Natural Gas (CNG) should be included to reduce the high dependence on the fossil fuels (i.e. fuel switching) as well as to push-up the energy supply. The main reason for choosing CNG as an alternative fuel is its high proven reserves in Egypt (enough to continue 73 years).

### 7.2.1 Reducing Travel Demand

Based on the study “The underground Transport System as a Mitigation option for GHG-Emissions” [61], the permanent population in the Alexandria Region in the year 2015 will be in the order of 5.35 Mil. inhabitants, i.e. some 2.00 Mil. more than in 1996.

In the contrary of the Most European Cities, the residential densities in the Egyptian cities are very high. That is means that a new land use plan for Alexandria, including prohibiting the vertical development in the crowded areas and encouraging the horizontal development in the new build-up areas, is urgently needed. Without control of the distribution of the future population growth within Alexandria, densities in some of the already congested areas may reach a figure of about 110,000 inhabitant per square kilometer; i.e. more travel demand on the overcrowded streets.

In order to reduce the travel demand in the crowded zones as well as to increase the development in the suburbs the following procedures are suggested [35]:

- The projected population of the urbanized zones without means of horizontal expansion should be determined, and the excess in population due to excessively high densities should be subtracted from the total expected increase.
- Projected population densities of the urbanized zones without means of horizontal expansion should not exceed those in the year 1996.
- For the urban zones with possibility of horizontal expansion, the projected population should be used as an approximation for likely infill.
- Maximum suggested growth rates of 10 - 12 percent per annum should be applied to the new build-up areas in Amria, as well as in Montazah, Raml and Sidi Gaber (South of the Abou Kir railway).
- For the estimation of urban land requirements, a maximum zone density of 80,000 inhabitant per square kilometer should be applied.

Table 7.1 presents the distribution of the population in the year 1996 and their predictions for the year 2015 in both cases; business-as-usual and sustainable development. It shows how the additional population, would be accommodated within the urban zones in the two cases.

**Table 7.1: Population projections and Densities for the years 1996 and 2015**

| Zones | 1996 | | Business-as-Usual 2015 | | Sustainable Development 2015 | |
|---|---|---|---|---|---|---|
| | Population *(x 1000)* | Density *(100 inh./km²)* | Population *(x 1000)* | Density *(100 inh./km²)* | Population *(x 1000)* | Density *(100 inh./km²)* |
| **1. Minaa El Bassal** | 300.0 | 136.5 | 358.3 | 163.0 | 300 | 136.5 |
| **2. Mina of Alexandria** | -- | -- | -- | -- | -- | -- |
| **3. Gomrok** | 124.0 | 815.1 | 151.7 | 997.5 | 121.7 | 800.0 |
| **4. Labban** | 64.3 | 751.5 | 77.0 | 899.8 | 64.3 | 751.5 |
| **5. Karmouz** | 197.5 | 653.0 | 237.8 | 786.1 | 197.5 | 653.0 |
| **6. Ameriya** | 170.0 | 0.3 | 410.8 | 0.73 | 490.0 | 0.89 |
| **7. Dekheila** | 110.8 | 18.0 | 167.0 | 27.2 | 176.1 | 28.7 |
| **8. Mansheyah** | 39.0 | 608.9 | 48.6 | 758.4 | 39.0 | 608.6 |
| **9. Attarin** | 67.4 | 385.7 | 85.6 | 489.9 | 67.4 | 385.7 |
| **10. Moharram Bek** | 390.0 | 720.9 | 583.3 | 1078.2 | 390.0 | 720.9 |
| **11. Bab Sharkhy** | 227.6 | 503.4 | 332.3 | 735.0 | 227.6 | 503.4 |
| **12. Sidi Gaber** | 180.0 | 141.5 | 267.2 | 210.1 | 400.0 | 314.5 |
| **13. Raml** | 650.0 | 472.6 | 862.4 | 627.1 | 1080.0 | 785.3 |
| **14. Montazah** | 850.0 | 40.6 | 1776.0 | 84.8 | 1804.4 | 86.2 |
| **Total** | **3370.0** | | **5358.0** | | **5358.0** | |

The table indicates that zones 4, 5, 8, 9, 10 and 11 are already severely overcrowded, and as a consequence, population should stabilize or decrease. On the other hand, the zones that will experience the greatest absolute increase in population are those of Ameriya, Dekheila, Montazah, Raml and Sidi-Gaber. Such population projection should help in the development of new residential and service areas; i.e. leading to the increase in work places and employment along the new development axes [24].

### 7.2.2 Modal Shift

The limited capacity of the urban transport infrastructure in Alexandria to cope with growing traffic volumes call for modal shift to favor public transport. The following two strategies can be applied in order to achieve modal shift in Alexandria:

*a) New Regional-Urban Railway*

With a view of a modal shift from road transport to an environmentally more friendly transport systems and to cover the rapid increase in the transport demand in Alexandria, it is proposed here the introduction of a large-scale rapid transit network.

According to the study “Introduction of Regional-Urban Railway System in Alexandria, 2000” [35], the proposed large-scale rapid transit network should include the following two main systems (Figure 7.1):

1- Abou Kir Regional Rail line from Abou Kir to Amria.
2- Raml Tram Urban line from Victoria to Kabary.

To realize this network the following measures are needed [35]:

- Upgrading the existing Abou Kir railline line from Abou Kir to Masr Station at Gomhoreya Square as well as its extension to Amria. The line contains about 6km underground section (between Gomhoria and Kabary).
- Upgrading the existing Raml Tram from Victoria to Orabi and extending it to Kabary. The line includes about 6 km underground section in the central area.
- Constructing of about 6 km underground Metro System from Gomrok to Moharem Bek.

However, it is expected great delays by realizing the proposed large-scale rapid transit network due to the inexistence of investments. In addition, a long time is needed for planning and construction as well as for placing the underground infrastructure (electricity, sewage, water supply, etc.). Thus, the improvement of the existing bus system in Alexandria, is the quickest and most effective way to increase the public transport capacity over the short term. Especially in bus transport, it would be possible to implement low cost measures which could be effected within a short time, and carried out without disrupting every day traffic flow. The developing policy of the bus system in Alexandria includes, among others, the following measures:

- Re-organization of bus line network with the aim of minimizing the mileage of indirect routes.
- Using traffic light system with bus priorities.
- Road development planning with considerations given to bus lanes and bus stop bays.

The distribution of the demand by mode in Alexandria under the proposed large-scale rapid transit network was projected as follows [61] (Figure 7.2):

| | | | |
|---|---|---|---|
| - Public Bus | 12.0 % | - City Tram | 12.0 % |
| - Private Bus | 6.00 % | - Taxi | 4.00 % |
| - Microbus | 6.00 % | - Private Car | 10.0 % |
| - Regional-Urban System | 50.0 % | | |

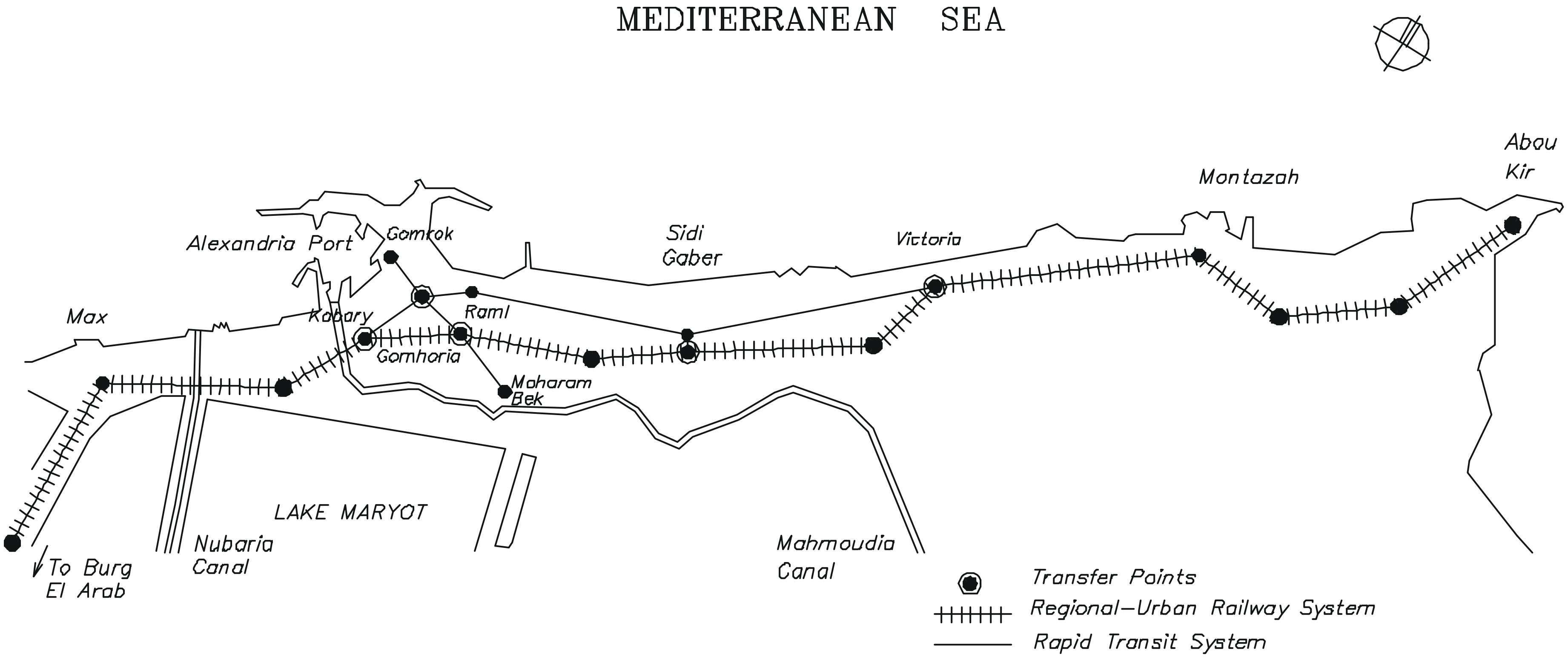



**Figure 7.1: The Proposed Regional-Urban Railway System, in Alexandria [35]**

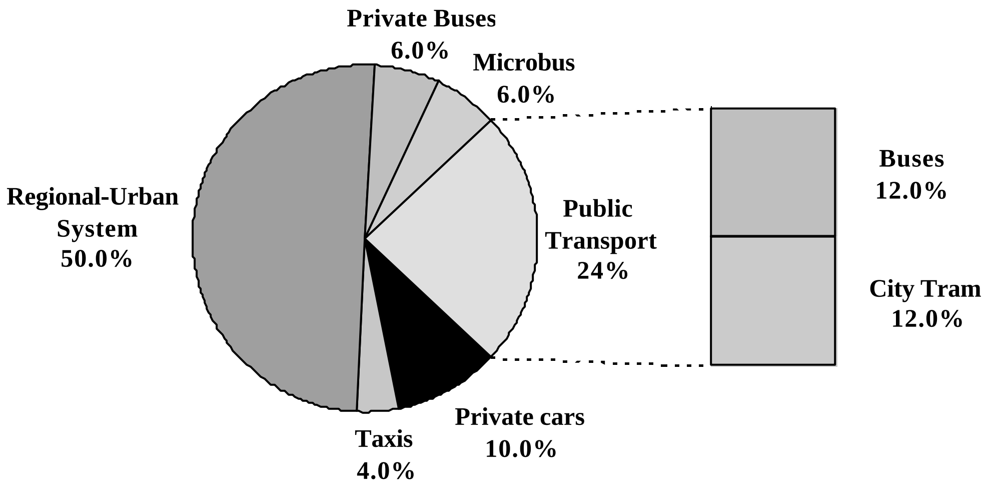



**Figure 7.2: Distribution of Demand by Mode under the proposed large-scale rapid transit network**

It should be noted that the introduction of this network will not only affect the modal split but also the population distribution in the different zones. New development axes along the proposed new lines will be created to serve the urban development in some zones as shown in Figure 7.3. Thus the distribution of the population in the case of sustainable development listed in Table 7.1 can be successfully applied with the introduction of the proposed network.

*b) High Fuel Price*

The principal impact of fuel price policies would be on the modal split. Fuel price policies raise the cost of vehicle trips and thus increase the attractiveness of alternative modes, including transit, ridesharing and non-motorized options. In addition, the revenue can be used for the improvement and investment of different public transport systems.

Mode choice analysis can be approached through application of pricing elasticity estimates from empirical studies. A simple definition of price elasticity is that it is a measure of how demand is sensitive to changes in price [69]. It must be stressed that elasticities will vary widely from region to region, depending on base costs, travel times, and mode shares as well as socio-economic factors.

Johansson and Schipper (1997) report fuel price elasticities of demand using a variety of models applied to a dozen of the countries [14]. Values of - 0.55 to - 0.05 for the elasticity of private car demand with respect to fuel price. With the value of - 0.3 assumed here, a price increase of 100 % in real terms leads to 30 % reduction in private car demand. Assuming that this benefit will

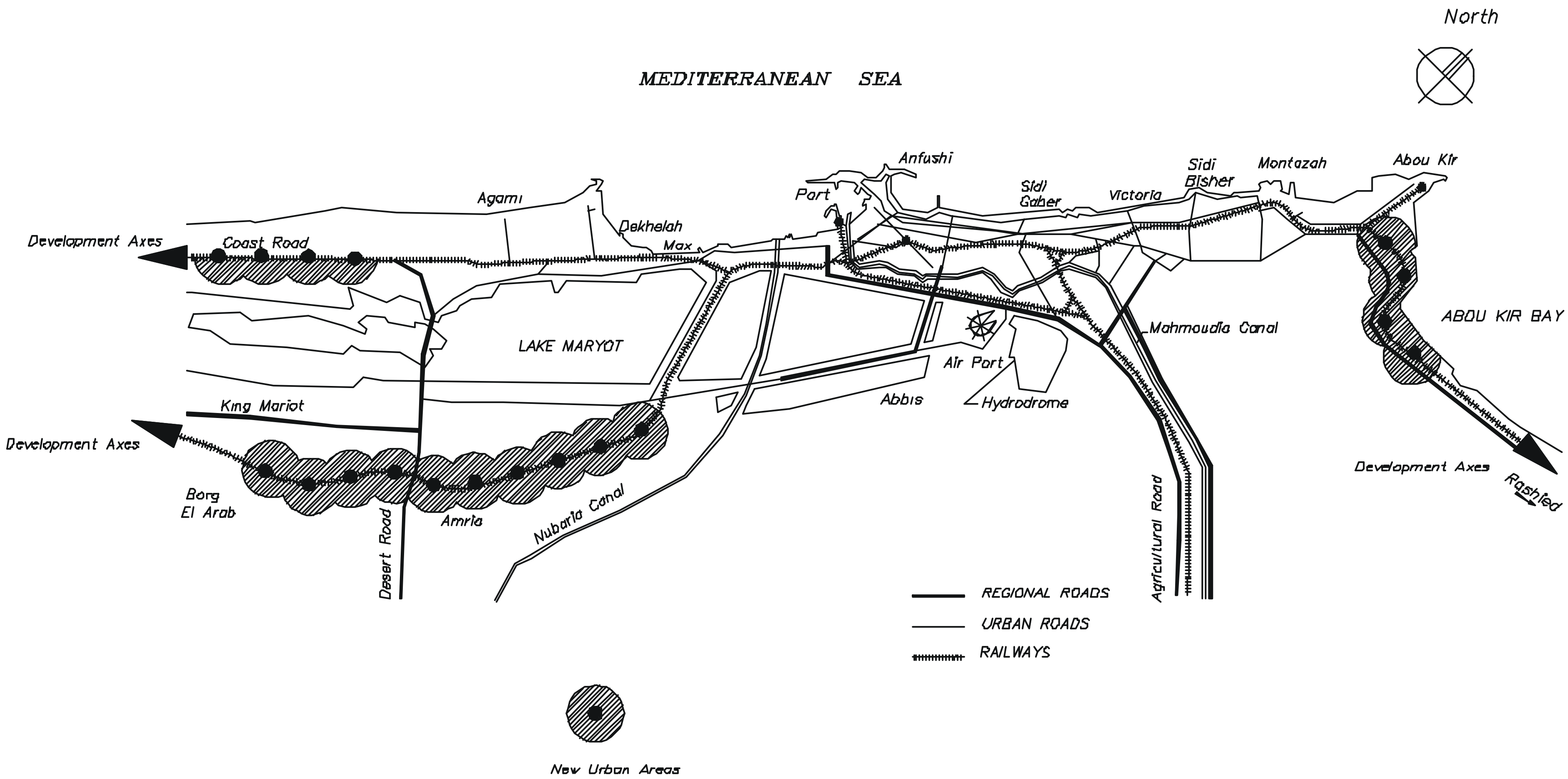



**Figure 7.3: The New Development Areas along the proposed new Lines [35]**

distribute on other modes according to its relative weights, the expected modal split for Alexandria can be calculated.

### 7.2.3 Smoothing Traffic

At present, the traffic flow condition in Alexandria is unstable with a volume/capacity ratio of about 1.04 in 1996 [35]. Therefore the following actions are prepared and tested in the framework of this study to improve the traffic condition in Alexandria:

a) Re-classification and assignment of the main roads on the network
b) Improving the accessibility in central areas through the creation of car-free zones and the introduction of a traffic management system.

Figure 7.4 presents a proposal for classification and assignment for main roads in the central area as well as the introduction of the new pedestrian area.

### 7.2.4 Intensive Use of CNG

Natural gas as an alternative fuel is considered as one of the main important options for fuel switching in Egypt. The main reasons are:

- The total proven reserves of natural gas in 1999 was about 31.5 thousand cubic meter (TCM), enough to continue about 73 years at present consumption rates compared to 11 years for oil(Table 7.2).

**Table 7.2: Review of Egypt Energy (Mtoe), 1999**

| Oil | | | | Natural Gas | | | |
|---|---|---|---|---|---|---|---|
| **Production** | **Consumption** | **Proved Reserves** | **R/P Ratio** | **Production** | **Consumption** | **Proved Reserves** | **R/P Ratio** |
| **42.9** | **27.3** | **500** | **11.4** | **11.0** | **11.0** | **802.5** | **72.9** |

Data Source: [6]

.- Egypt has developed some policies to support the expansion of natural gas utilization in various economic sectors, this includes [69]:
  - Developing gas infrastructure, where the natural gas pipeline grid has expanded from 1000 to more than 3000 km currently.
  - Promoting foreign investments in gas exploration and production. This is implemented through the addition of gas clause to the concession agreements that allowed foreign companies to share gas discoveries with the government of Egypt in the same manner used in oil.
- Egypt has developed some policies to support the utilization of compact natural gas (CNG) as a fuel for vehicles in Egypt, this includes [69]:

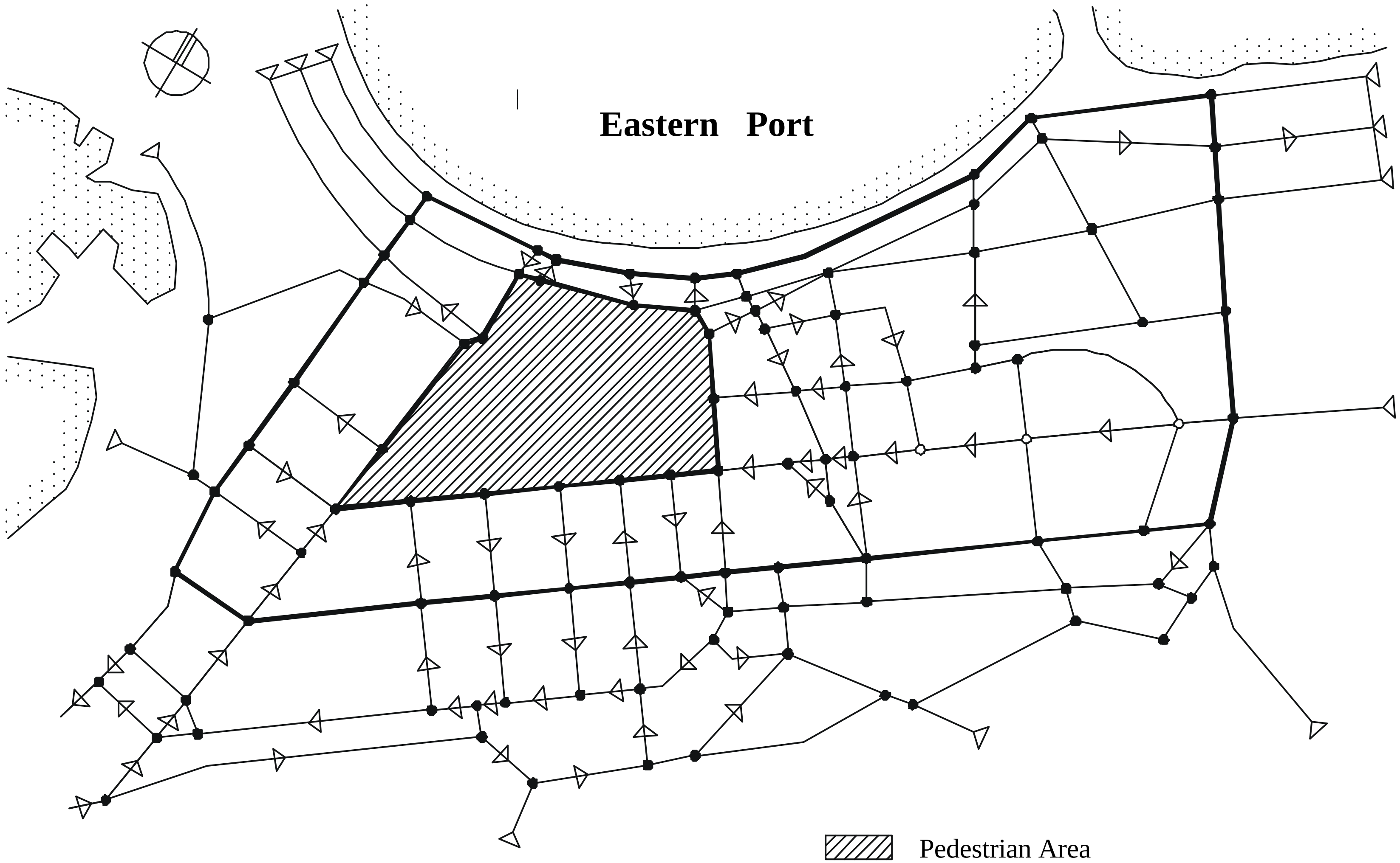



**Figure 7.4: Classification and Assignment of the Alexandria central Area Roads**

- The Social Bank in cooperation with the Egyptian Environmental affairs Agency dedicated about 40 Mil. L.E. as a soft loan for taxi and microbus drivers in order to convert about 70.000 taxi and 15.000 Microbus to operate with dual fuel cycle with both gasoline and natural gas.
- An agreement between Ministry of Petroleum and Ministry of Insurance and Social Affairs has been signed to encourage the use of CNG as a fuel for vehicles. According to that agreement, Naser Social Bank will make available for vehicle owners soft loans for converting their vehicle to operate with dual fuel cycle.

Giving the existing and expected situation of natural gas supply in Egypt (proven reserves, production levels, and distribution network), it is assumed here that the use of CNG as an alternative fuel for vehicles in Alexandria could be extended with a considerable share of total demand fuel during the coming years. Table 7.3 shows the projected shares for fuel type distribution according to transport mode in the year 2015.

**Table 7.3: Fuel Type Distribution (%)**

| Transport Mode | Fuel Type | | |
|---|---|---|---|
| | Gasoline | Gas Oil | CNG |
| **Private Car** | 80 | 5 | 15 |
| **Taxi** | 85 | 5 | 20 |
| **Microbus** | - | 80 | 20 |
| **Public Bus** | - | 75 | 25 |
| **Private Bus** | - | 75 | 25 |

## 7.3 Development of Future Scenarios

To evaluate the future transportation situation for Alexandria in the year 2015 and its technical, environmental and economical impacts, the "scenario technique" can successfully be adopted. The aim is to span the range of possible future and to provide various development strategies; i.e. the scenarios are based on different philosophies [70]. A scenario can be defined as a logical and plausible (but not necessarily probable) set of events that may lead to the future situation [24]. Then the scenarios should be compared with each other to select the best solution. The following four scenarios are developed in the framework of this study for the future development of the transport system in Alexandria (Table 7.4):

***Reference Scenario O: Business-as-usual Scenario (Do-Nothing Solution)***

The Reference Scenario is based on continuation of the existing travel behavior of the year 1996 in the future, according to the following assumptions:

- About 5.3 Mil. inhabitants will live in Alexandria in 2015 [61].
- Little change in the modal split to the benefit of the bus mode.
- No change in the future distribution of population among the different zones.
- No change in the road infrastructures of the year 1996.

***Scenario A: (Do-Minimum Solution)***

Scenario A includes some of the measures for saving, shifting, and smoothing traffic described in Section 7.2. The main features of this scenario can be summarized as follows:

- Improving the traffic condition on the main roads and traffic accessibility in central areas.
- Improving of the existing public transport system through:
  - Re-organization of bus network with the aim of minimizing the mileage of indirect routes.
  - Usage of modern rail cars.
  - Increase of distances between stops for the Rail systems.
- Switching fuel through the intensive use of CNG.

***Scenario B: (Do-Something Solution)***

Scenario B includes the measures of scenario A plus measure of upgrading the existing Abou Kir railline from Abou Kir to Masr Station at Gomhoreya Square as well as its extension to Amria. This line contains about 6 km underground section (between Gomhoria and Kabary).

The main future of this scenario beside the suggested modal split is the reduction of the transport demand through creating new human settlements along the proposed lines to serve the urban development.

***Scenario C1: (Do-Maximum Solution I)***

Scenario C1 includes the measures of scenario B plus measures of (Figure 7.1):

- Upgrading the existing Raml Tram from Victoria to Orabi and extending it to Kabary. The line includes about 6 km underground section in the central area.
- Constructing of about 6 km underground Metro System from Gomrok to Moharem Bek.

The main feature of this scenario is its complete dependence on a new public transport system (large-scale rapid transit network) to attract some car users and to cover the increasing travel demand, and therefore, reducing the congestion of the overcrowded roads.

***Scenario C2: (Do-Maximum Solution II)***

The disadvantage of Scenario C1 is the high investment budget needed and the inexistence of financial sources. Therefore, a new scenario is needed. Scenario C2 includes the measures of scenario C1 plus measure of increasing the fuel price by 100 % in the real terms. This measure not only helps to pull the people from the private cars, but also can finance the proposed large-scale rapid transit network [34].

**Table 7.4: Development of Scenarios by Combining the Measures**

| Combination of Abatement Measure | Measures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | |
| **Reference Scenario O** | -- | -- | -- | -- | -- | -- | -- | -- | **Do-Nothing Solution** |
| **Scenario A** | ✓ | ✓ | ✓ | -- | -- | -- | -- | -- | **Do-Minimum Solution** |
| **Scenario B** | ✓ | ✓ | ✓ | ✓ | ✓ | -- | -- | -- | **Do-Something Solution** |
| **Scenario C1** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | -- | **Do-Maximum Solution I** |
| **Scenario C2** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | **Do-Maximum Solution II** |

M1: Improving the traffic condition, M2: Improving of the existing public transport system, M3: Intensive Use of CNG, M4: Reducing travel demand through using the sustainable development of population, M5: Upgrading the existing Abou Kir railline from Abou Kir to Masr Station at Gomhoreya Square and extending it to Amria, M6: Upgrading the existing Raml Tram from Victoria to Orabi and extending it to Kabary, M7: Constructing of about 6 km underground Metro System from Gomrok to Moharem Bek, and M8: Increasing the fuel price by 100 % in the real terms.

Based on the modal split for Alexandria in the year 1996 and according to the model shift concept presented in Section 7.2.2, the distribution of the demand by mode for the different scenarios in 2015 are determined (Table 7.5).

**Table 7.5: Distribution of Demand by Mode for different Scenarios in 2015**

| Mode | Modal Split (%) | | | | |
|---|---|---|---|---|---|
| | Reference Scenario O | Scenario A | Scenario B | Scenario C1 | Scenario C2 |
| **Private Car** | 16.0 | 14.2 | 12.4 | 10.0 | 7.0 |
| **Public Bus** | 20.6 | 22.1 | 20.8 | 12.0 | 12.6 |
| **Private Bus** | 10.6 | 11.0 | 10.2 | 6.0 | 6.3 |
| **Microbus** | 13.2 | 14.8 | 14.2 | 6.0 | 6.3 |
| **Taxis** | 6.5 | 5.0 | 4.6 | 4.0 | 2.8 |
| **Abou Kir** | 4.8 | 4.8 | 9.0 | 50.0* | 52.4* |
| **Raml Tram** | 13.5 | 13.8 | 14.0 | | |
| **City Tram** | 14.8 | 14.3 | 14.8 | 12.0 | 12.6 |
| **Total** | 100 | 100 | 100 | 100 | 100 |

* *Regional-Urban Railway*

For the different scenarios, the future O-D matrices are calculated using the Average-Factor Method. Then "VISUM" program is applied to predict the travel conditions on the different links of the proposed scenarios road networks as well as the effectiveness of the suggested public transport systems. Also, "DYNAMIS" and "TraEnergy" programs are used in order to predict the total energy consumption and emissions under the different proposed scenarios.

## 7.4 Evaluation of Scenarios

### 7.4.1 Technical Impacts

#### 7.4.1.1 Number of used Vehicles

From the transportation point of view, the operated vehicles numbers in an urban area depends on the effectiveness of the public transport system and/or the mobility price for the private cars (e.g. fuel price).

Table 7.6 shows the calculated number of operating vehicles in the peak hour on the whole road network of Alexandria in the year 2015, under the business-as-usual scenario and the proposed other scenarios. It presents also the number of vehicles in case of realizing the different Scenarios, compared with those of the Reference Scenario. The best solution for Alexandria is Scenario C2 (which include the introduction of the large-scale rapid transit network and the high fuel price), in which the number of used vehicles in the peak hour is estimated to be about 30.3 thousand.

**Table 7.6: Estimated No. of Vehicles operated on Alexandria Network in the Peak Hour**

| Mode | Reference Scenario O | Scenario A | Scenario B | Scenario C1 | Scenario C2 |
|---|---|---|---|---|---|
| **Private Car** | 43251 | 33519 | 28653 | 27032 | 18922 |
| **Taxi** | 13780 | 10600 | 9328 | 8480 | 5936 |
| **Public Bus** | 1859 | 2075 | 2076 | 1083 | 1137 |
| **Private Bus** | 1510 | 1567 | 1567 | 855 | 897 |
| **Microbus** | 7305 | 8301 | 8301 | 3320 | 3486 |
| **Total** | **67705** | **56062** | **49925** | **40770** | **30378** |
| **Additional No. of vehicles from the Reference Scenario** | **0.0** | **11643** | **17780** | **26935** | **37327** |

#### 7.4.1.2 Mobility

Figure 7.5 shows the development of the expected mobility (not based on calculations) from 1996 to 2015. In the year 1996, the mobility has achieved 0.8 trip/inh./day. This is result of congestion as well as the insufficient public transport systems. Furthermore, more drop in the mobility (about 0.75 trip/inh./day) is also expected in the Reference Scenario O due to the high growth in the use of private car on the same traffic areas. In Scenario A, with a mobility of about 0.85 trip/inh./day, the traffic condition would be slight better than the traffic condition in the case of Reference Scenario O.

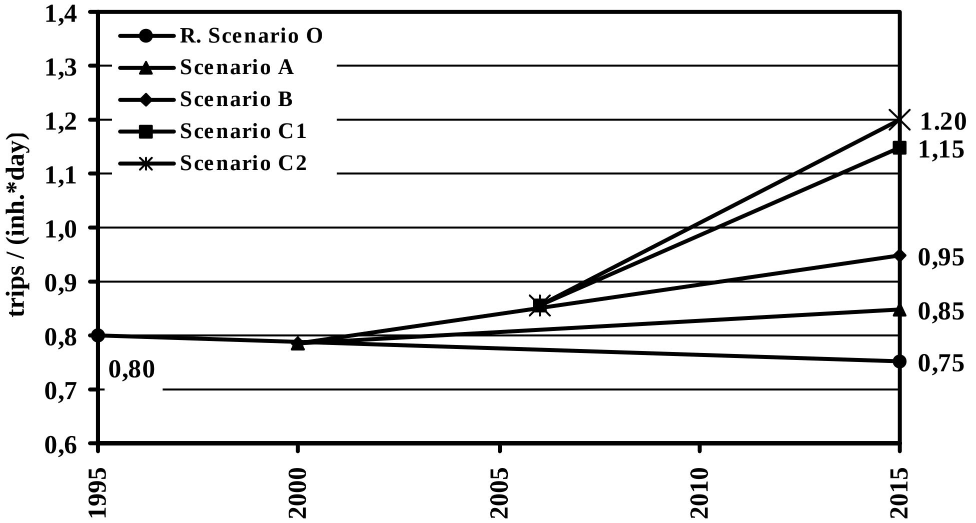



**Figure 7.5: Mobility Development until 2015**

The mobility of about 1.15 trips/(inh.*day) may be reached in the year 2015 by realizing Scenario C1. This scenario includes different powerful public transport systems which is designed to cover the fast increase in travel demand and to improve the level of service on Alexandria urban road network. An increase in the mobility indicates improving the economic situation and the living standard [24].

#### 7.4.1.3 Average Saturation Degree

VISUM program calculates and presents the average saturation degree on the road network for the year 1996, as well as for the different scenarios of the year 2015. Figure 7.6 presents the average saturation degree on Alexandria network.

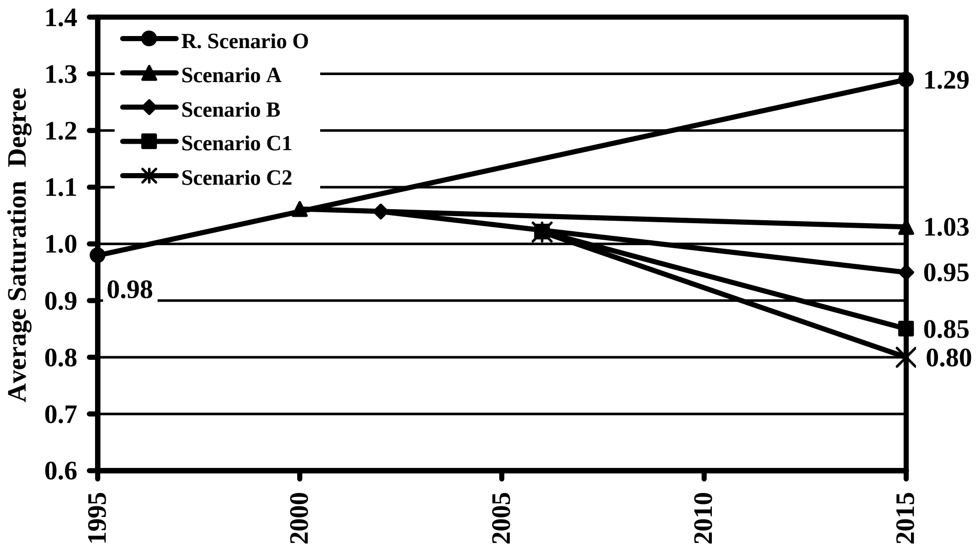



**Figure 7.6: Average Saturation Degree on Alexandria Network**

Under the different scenarios, great improvement of the average saturation degree can be achieved. For example under scenarios C1 and C2 (Do-maximum solution), the average saturation degrees are 0.85 and 0.8 respectively compared with 1.29 under the Business-as-usual Scenario. Figure 7.5 and 7.6 show that, the benefits of the Scenarios B, C1 and C2 (which include the introduction of new public systems) may begin after the other Scenarios.

#### 7.4.1.4 Average running Speed

A drop in the average saturation degree on an urban road network is linked with growing the traffic volumes on the road network. The result of such a drop is a reduction in the average running speeds on the roads (individual or as a network) as well as an increase in the traffic delays per one kilometer length of road [24]. Figure 7.7 presents the results calculated by VISUM program for the year 1996 as well as the different scenarios.

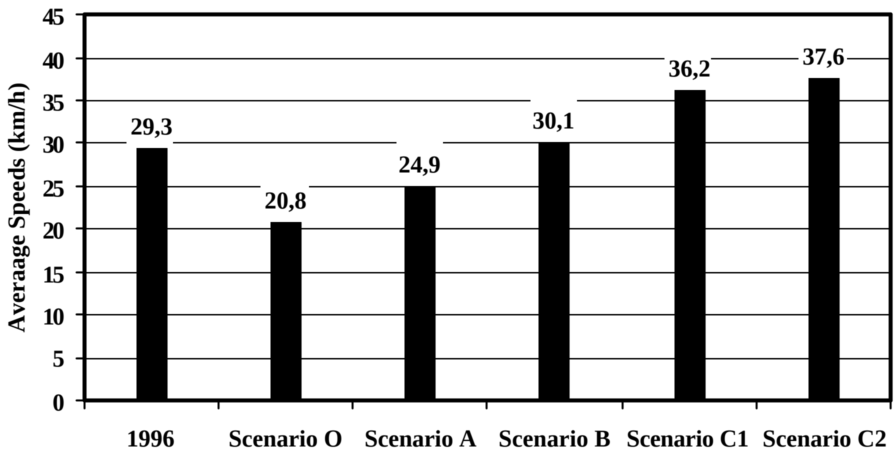



**Figure 7.7: Average Speeds on the Road Network**

As shown in this Figure, Scenarios C1 and C2 are the best solutions. In these scenarios, the average running speeds on the road network are expected to be 36.2 km/h and 37.6 km/h respectively.

### 7.4.2 Environmental Impacts

#### 7.4.2.1 Energy Consumption

*a) Future Energy Consumption Rates*

Figure 7.8 shows the expected distribution of private car according to the age in the year 2015. As can be seen, there will be significant share of new vehicle (up to 5 year) in the Alexandria fleet. The reason of this is due to:

- the expected reduction in the new vehicle price because of the GATT Agreement.

- the continuous improvement in the level of income, and
- the expansion of vehicle production in Egypt.

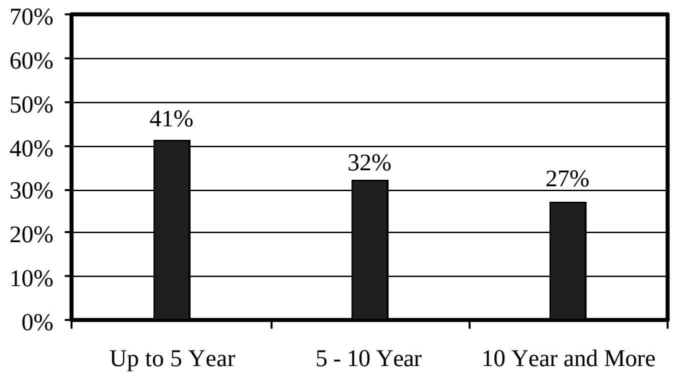



**Figure 7.8: Passenger Car Distribution According to the Age, Alexandria 2015**

According to the expected distribution of private car's classes in Alexandria and the new trends in fuel efficiency for new vehicles the expected fuel consumption rates for the private car is determined. Table 7.7 presents the expected fuel consumption rates (FCR) for the private car according to the distribution of age classes as well as the calculated composite fuel consumption rate.

**Table 7.7: Fuel Consumption Rates (FCR) of Private Car in 2015 (Gasoline)**

| Mode | Class | FCR (l/100km) | Prevalence (%) | Composite FCR (l/100km) |
|---|---|---|---|---|
| Private Car | Up to 5 Years | 9 | 41 | 9.86 |
| | 5 – 10 Years | 10 | 32 | |
| | 10 Years and More | 11 | 27 | |

Table 7.8 presents the expected fuel consumption rates for different road transport modes in Alexandria. These rates are found to be suitable at the average speeds listed in the table.

**Table 7.8: Fuel Consumption Rates for different Transport Modes in Alexandria, 2015**

| Mode | Average Speed Km/h | FCR by Fuel Type (l/100km) | | |
|---|---|---|---|---|
| | | Gasoline (l/100km) | Gas Oil (l/100km) | Natural Gas ($m^3$/100km) |
| Private Car | 30-40 | 9.86 | 13.1 | 11.1 |
| Taxi | 30-40 | 15.2 | 15.8 | 12.5 |
| Microbus | 30-40 | - | 20.5 | 20.5 |
| Public Bus | 20-30 | - | 48.9 | 48.9 |
| Private Bus | 20-30 | - | 41.5 | 41.5 |

For rail transport, the specific power consumption for the proposed regional rail line from Abou Kir to Amria section is calculated using DYNAMIS program. ANNEX II presents the output data and graphics from DYNAMIS for the Abou Kir railway line (Figures C and D). Table 7.9 presents the specific power consumption for the proposed Regional-Urban Railway.

**Table 7.9: Specific Power Consumption for the Proposed Regional Rail Line**

| Direction | Specific Power Consumption (kWh/trip) | Direction | Specific Power Consumption (kWh/trip) |
|---|---|---|---|
| **From Abou Kir to Amreyah** | 256.53 | **From Amreyah to Abou Kir** | 268.31 |

*b) Total Energy Consumption*

Using the output data from the assignment (i.e. activities and average speeds) as an input data in the TraEnergy computer system, explained in Chapter 4, the energy consumption for road transport modes is calculated in the year 2015 under the different scenarios. For the rail transport modes, the total energy consumption is calculated based on the specific power consumption (output from DYNAMIS program).

Table 7.10 and Figure 7.9 summarize the results obtained from calculations. The total energy consumption needed for the passenger transport in Alexandria under Reference Scenario O (Business-as-usual) will achieve 10.675 PJ in the year 2015; i.e. with an increase rate of about 101 % of the consumption in the year 1996 (5.319 Pj).

**Table 7.10: Total Energy Consumption under the different Scenarios for Alexandria/year**

| Scenario | Energy Consumption (Tj) | | | | |
|---|---|---|---|---|---|
| | **Gasoline** *(Mill. Lit.)* | **Gas Oil** *(Mill. Lit.)* | **N. Gas** *(Mill. $m^3$)* | **Electricity** *(1000 kWh)* | **Total** *(Tj)* |
| **1996** | 90.809 | 58.379 | 0.000 | 38536 | 5319 |
| **Reference Scenario O** | 184.577 | 115.263 | 0.000 | 77813 | 10675 |
| **Scenario A** | 117.038 | 105.450 | 35.944 | 85594.3 | 8309 |
| **Scenario B** | 90.123 | 87.206 | 28.531 | 157654 | 7526 |
| **Scenario C1** | 62.664 | 43.871 | 18.887 | 249326 | 6004 |
| **Scenario C2** | 54.411 | 42.204 | 17.720 | 274258.6 | 5935 |

Under Scenario C1 and C2, great reductions of the energy consumption are expected (about 43 % for scenario C1 and 44% for scenario C2 energy less than those of the business-as-usual scenario "Reference Scenario O"). The reasons can be summarized as follows:

- The intensive modal shift from road transport to public transport; particularly because of the urban-regional transit system.
- The improvement of the traffic conditions on the road network.

- The fuel switching from fossil fuels to electricity and natural gas.

Scenario A, which does not include the introduction of urban-regional transit system or high fuel price measure, has only limited effect in reducing the energy consumption.

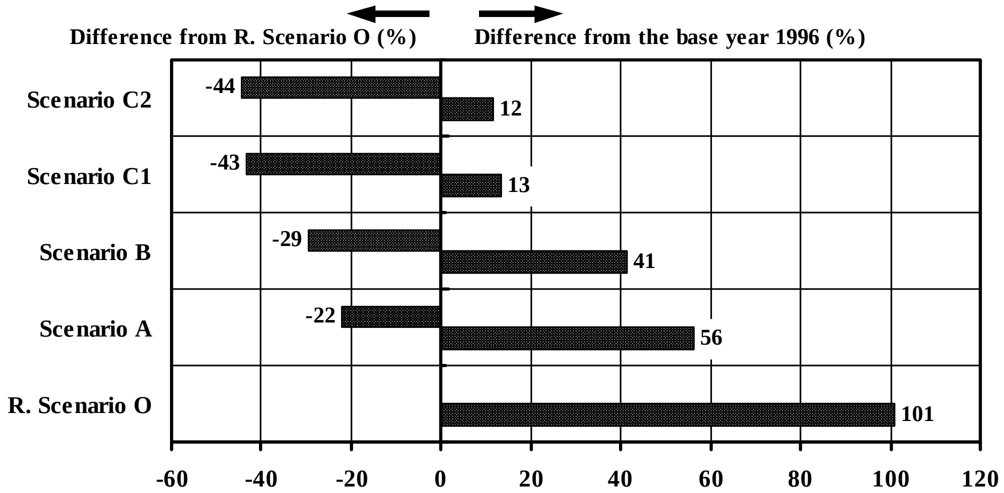



**Figure 7.9: Energy Consumption Differences (in %) under different Scenarios from the Situation of the Base Year 1996 and the Reference Scenario O 2015**

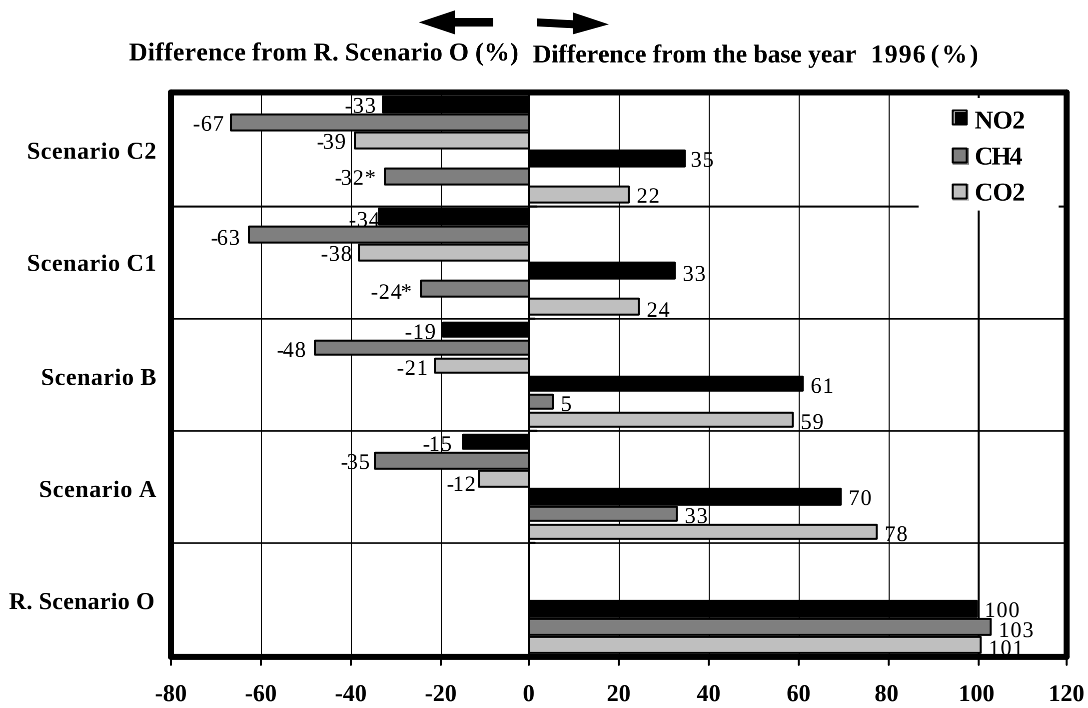
### 7.4.2.2 GHG-Emissions

Table 7.11 and Figure 7.10 present the total GHG-emissions (carbon dioxide CO2, methane $CH_4$, and $NO_2$ for example) calculated by the "TraEnergy Program" for the year 1996, as well as for the different scenarios of the year 2015. In Reference Scenario O, the amount of GHG-emissions will achieve 798.722 kilo-ton $CO_2$, 591.992 tons $CH_4$ and 379.182 tons $NO_2$; i.e. with increase rates of about 100 % of those emitted in the year 1996.

**Table 7.11: Total GHG-emissions under the different Scenarios for Alexandria/year**

| Scenario | TOTAL GHG-emissions | | |
|---|---|---|---|
| | $CO_2$ *(kilo-ton)* | $CH_4$ *(ton)* | $NO_2$ *(ton)* |
| **1996** | 397.676 | 291.676 | 189.791 |
| **Reference Scenario O** | 798.722 | 591.992 | 379.182 |
| **Scenario A** | 706.640 | 387.313 | 322.015 |
| **Scenario B** | 630.603 | 307.285 | 305.477 |
| **Scenario C1** | 494.573 | 220.572 | 251.563 |
| **Scenario C2** | 486.640 | 197.312 | 255.307 |

Under the different scenarios, great reductions of the GHG-emissions are expected. For example under scenario C2 (Do-maximum solution II), about 39 % CO2, 67 % CH4 and 33 % NO2 less than those of the Reference Scenario O.




* Difference from the Base Year 1996

**Figure 7.10: GHG-Emissions Differences (in %) under different Scenarios from the Situation of the Base Year 1996 and the Reference Scenario O**

### 7.4.2.3 Gases with Direct Health Effects

Figure 7.11 and 7.12 present the average amounts of the gases with direct health effects (for example, carbon monoxide CO, and hydrocarbon HC) per one km length of the road network for different road types under different scenarios. The roads are classified according to the residential density level (high, medium and low) in order to recognize that there are differences in the effects of these emissions on the people according to their resident place.

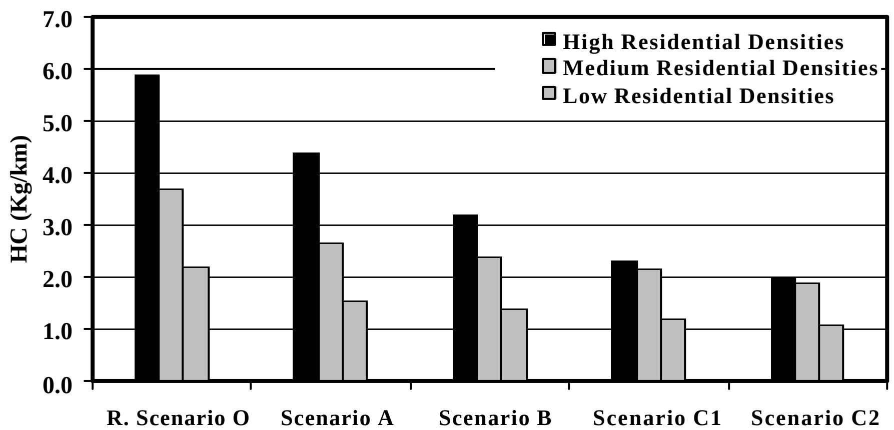



**Figure 7.11: Average Amounts of HC Emissions under the Different Scenarios for different road types**

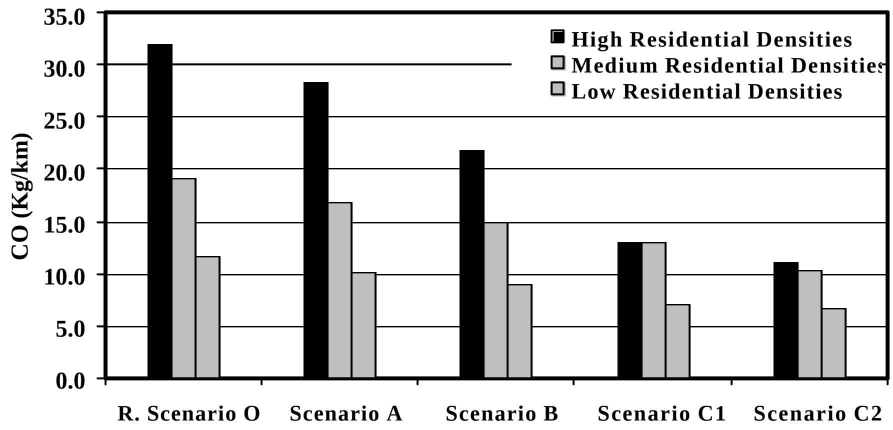



**Figure 7.12: Average Amounts of CO Emissions under the Different Scenarios for different road types**

As can be shown from the figures, the roads which located in the high residential densities areas have always the maximum amount of gases with direct health effects. Scenarios C1 and C2, which include the introduction of urban-regional transit system, has great reductions of the CO and HC emissions in the high residential densities areas. The reason is that large part of the proposed urban-regional transit system is located in the high residential density areas.

### 7.4.3 Economical Impacts

#### 7.4.3.1 Capital and Operation Costs

In the framework of the study "Introduction of Regional-Urban Railway System in Alexandria, 2000" [35], the capital and the operating costs of the proposed rapid transit network were calculated. In Scenario C1 the investment costs will be 6240 Mil. L.E.. The total operating costs on the rapid transit network were expected to be 0.312 L.E. per passenger-km including the depreciation and the final charges and excluding environment damage.

These enormous capital and operating costs call for financial support. Scenario C2 which includes high fuel price can be considered as a financial support. The revenue is estimated to be about 250 Mil. L.E. per year from the transportation systems in Alexandria only.

#### 7.4.3.2 Fuel Cost Saving

Based on the amounts of the different types of fuel needed for the transport sector in Alexandria in the year 2015 under the different scenarios, the annual fuel costs are calculated according the 1998 prices, as well as the prices in the future. It is expected that fuel prices in the year 2015 may be about 1.7 times the existing prices [64]. Table 7.12 presents the fuel costs of the transport sector in Alexandria in the year 2015 under the different scenarios. It shows that annual saving in the fuel cost under the different scenarios, compared with the Reference Scenario, would be about 92.0, 137.0, 196.7, and 206.2 Mil. L.E. respectively per year. In other words, the costs of fuel needed in the future will be about twice the costs, without Scenario C2 (for example).

**Table 7.12: Annual Fuel Costs for Transportation in Alexandria**

| Scenario | Unit Price | | Reference Scenario O | | Scenario A | | Scenario B | | Scenario C1 | | Scenario C2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fuel Type** | **Unit** | **98 prices L.E.** | **Fuel Demand** | **Fuel Cost** | **Fuel Demand** | **Fuel Cost** | **Fuel Demand** | **Fuel Cost** | **Fuel Demand** | **Fuel Cost** | **Fuel Demand** | **Fuel Cost** |
| **Gasoline** | **Liter** | **1.00** | 184.6 | 184.6 | 117.0 | 117.0 | 90.1 | 90.10 | 62.7 | 62.70 | 54.4 | 54.4 |
| **Gas Oil** | **Liter** | **0.40** | 115.3 | 46.10 | 105.5 | 42.20 | 87.2 | 34.88 | 43.9 | 17.55 | 42.2 | 16.9 |
| **Electricity** | **KWh** | **0.153** | 78.0 | 11.90 | 85.6 | 13.13 | 157.7 | 24.12 | 249.3 | 38.15 | 274.3 | 42.0 |
| **N. Gas** | **$m^3$** | **0.45** | 0.0 | 0.00 | 35.9 | 16.17 | 28.5 | 12.90 | 18.9 | 8.50 | 17.7 | 8.0 |
| **Total Cost – 1998 prices (Mil. L.E.)** | | | 242.6 | | 188.5 | | 162.0 | | 126.9 | | 121.3 | |
| **Total Costs – 2015 prices (Mil. L.E.)** | | | 412.4 | | 320.4 | | 275.4 | | 215.7 | | 206.2 | |
| **Annual Saving from the Reference Scenario (Mil. L.E.)** | | | 0.000 | | 92.0 | | 137.0 | | 196.7 | | 206.2 | |

### 7.4.3.3 Time Value

The value of time saving on a particular mode of travel is defined as the amount which an average traveler is willing to pay to save a small amount of time spent traveling [35]. In transport studies, value of estimates is necessary for forecasting transport demand and also in the evaluation of alternative plans. It is important to specify accurately the value assigned to time saving, since the most important benefit estimated from improvement in transportation systems is associated with saving in travel time. These benefits are usually presented in monetary terms by first forecasting the amount of time saved and then multiplying this amount by a value of time unit [35].

There are some efforts to determine the value of time in Egypt [61]. However, there is no specific trend of the time values in Egypt due to the random fluctuation. Thus, for the evaluation of alternative transit systems which may be realized at the target year, the saving trip time can be considered an indicator of the time value. Table 7.13 presents the annual total trip times for all modes (the trip time of each transportation mode is calculated and summed up) as well as the annual time saving.

**Table 7.13: Time Saving for all Modes, Alexandria 2015**

| Scenarios | Total Trip Time | Time Savings | Average Time Saving |
|---|---|---|---|
| | Million Hours / year | Million Hours / year | Minite Per Trip |
| **Reference Scenario O** | 2298.71 | -- | -- |
| **Scenario A** | 2211.06 | 87.65 | 2.68 |
| **Scenario B** | 2183.61 | 115.10 | 3.52 |
| **Scenario C1** | 2053.60 | 245.11 | 7.49 |
| **Scenario C2** | 2029.05 | 269.66 | 8.25 |

The calculations show that Scenarios C1 and C2, which include powerful public transport systems, are better than Reference Scenario O in terms of annual time savings and average time saving per trip (about 269 Mil. hours and 8.25 minute per trip consequently for Scenario C2).

## 7.5 Preparing Actions Program for a Sustainable Development of Energy Consumption

To achieve sustainable development for energy consumption in Alexandria at least two different sets of objects need to work together:

1- *Push-Down* the growth in energy consumption, through the sustainable development concept of mobility plan which include (Figure 7.13):

- Reduce travel demand through the sustainable development of the population
- Improve the traffic condition on the main roads and traffic accessibility in central areas.
- Introduce the proposed large-scale rapid transit network in order to reduce the use of private car and smooth the traffic
- Substantially higher fuel prices with the aim of improving and upgrading the public transport systems in Alexandria.

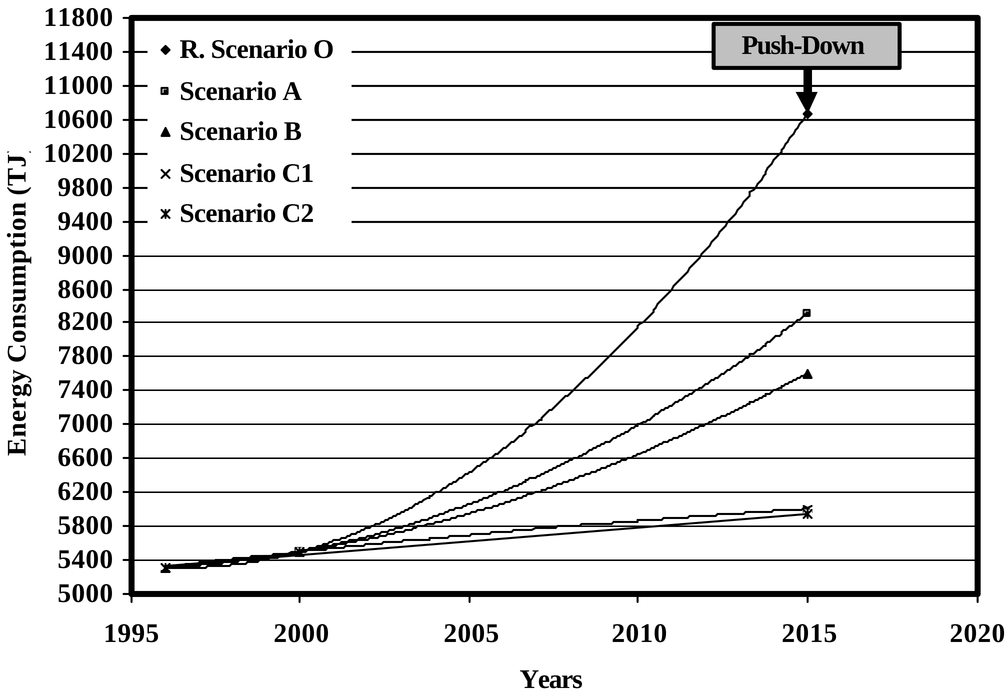



**Figure 7.13: Towards Sustainable Energy Consumption (Push-Down Approach)**

2- *Push-Up* the energy supply for transportation, through:

- Fuel switch from oil products to natural gas (as an alternative fuel) by providing strong financial incentive. Reasons for this is the high proven reserves of natural gas, about 802.5 Mtoe, enough to continue 72.9 years compares to proven reserves of only 500 Mtoe of recoverable oil enough to continue 11.4 years (Table 7.2).

# CHAPTER 8
# CONCLUSION AND RECOMMENDATIONS

The impact of modern development on the environment has long been a cause of concern at national and global levels. The rate and scale of the trends in environmental degradation, however, have been growing significantly with the improving of the standards of living. Growing environmental awareness has led to the belief that infinite growth within a finite system is untenable, and that the natural limits should be respected.

As a result of the expansion and development of the economy in general and the improvement of standard of living in particular, demand for transport of people and goods increases and consequentially energy consumption and pollutant emissions as well. Yet the increase in the quality of life, as a result of motorization, is starting to turn into the opposite direction; i.e. deteriorating living standards. The problems of high level of motorization, inefficient use of scare fossil fuel resources, emission of harmful pollutants and deterioration of quality of life are linked to such an extent we can say the "transport - energy - environment" problem.

In addition, in developing countries, rapid motorization and insufficient investments in urban-transport planning, traffic management and infrastructure are creating increasing problems in terms of accidents and injury, health, noise, and congestion. All of these problems have severe negative impacts on the urbanity and the lifestyle of the citizens in these countries.

Therefore, there is need for an examination of existing transport systems and for more effective design and management of the transport systems. The basic objective of a sustainable transport concept is the development of promote cost-effective urban and transportation policies, as appropriate, (a) to satisfy the travel demand, (b) to save energy and (c) to control harmful emissions into the atmosphere as well as other adverse environmental effects of the transport sector, taking into account the needs for sustainable social and economical development.

Traditional approaches to transportation planning (called also "Demand-oriented Planning") are based on the notion of "predict demand and provide facilities", i.e. meeting the travel demand by providing extra traffic infrastructure.

Building more and more roads in the cities and conurbation, where possible, enables more people to travel by car, but not reduces peak-period congestion to any noticeable extent. As soon as new roads space becomes available in large cities, it is quickly filled.

In the eighties, the increase in environmental awareness has highlighted the issue of transport as an important environmental problem. A wide consideration has been given to the transportation planning process to include noise and air pollution. The "Environment-oriented Transportation Planning" ensures minimum impact on the environment, by applying traffic calming measures, car use restrictions and parking control. Such anti-car techniques are used in a relatively piecemeal fashion up to now, so that cities still seem to be largely dominated by road traffic.

This means, the main effort is to change the transportation planning philosophy itself, from the traditional approach to sustainable transport; i.e. not to improve the environmental performance of an existing transport system, but to change the transport system itself with a view to the environmental constraints. The goals are: (1) to make sure that all road users are taken into consideration in a sustainable way, and (2) to generate new human settlements along development axes in the framework of integrated land use/transportation planning. This new philosophy is called "Sustainable-oriented Transportation Planning".

Moreover and for the aim of preparing sustainable energy consumption plan, switching to alternative fuels should be included to the whole concept in order to reduce the high dependence on the fossil fuels as well as to push-up the energy supply.

To investigate the technical, environmental and economical benefits of the proposed sustainable transportation and energy concept, an application to Alexandria is carried out. Five different scenarios are formulated for the future development of the transport system in the year 2015 in Alexandria:

**Reference Scenario O** "Business-as-usual Scenario (Do-Nothing Solution)". It is defined here as the solution based on the continuation of existing travel behavior in the future with limited changes in the urban structure, the transport infrastructure, and in the modal split.

**Scenario A** (Do-Minimum Solution). It includes some of the measures for saving, shifting, and smoothing traffic as well as the intensive use of CNG.

**Scenario B** (Do-Something Solution). It includes the measures of scenario A plus measure of upgrading the existing Abou Kir railline from Abou Kir to Masr Station at Gomhoreya Square as well as its extension to Amria.

**Scenario C1** (Do-Maximum Solution I). It includes the measures of scenario B plus measures of upgrading the existing Raml Tram from Victoria to Orabi and extending it to Kabary as well as constructing of about 6 km underground Metro System from Gomrok to Moharem Bek. The disadvantage of this scenario is the high investment budget needed and the inexistence of financial sources.

**Scenario C2** (Do-Maximum Solution II). This scenario includes the measures of scenario C1 plus measure of increasing the fuel price by 100 % in the real terms. This measure not only helps to pull the people from the private cars, but also can finance the proposed large-scale rapid transit network.

The evaluation of the various scenarios among others indicated that the maximum reduction of the energy consumption and its related emissions resulted from Scenarios C1 and C2 which are based on:

- The intensive modal shift from road transport to public transport; particularly because of the a large-scale rapid transit network.
- The improvement of the traffic conditions on the road network.
- The fuel switching from fossil fuels to electricity and natural gas.

Finally, Scenario C2 turned out to be economic-wise the best option based upon the high revenue from the extra fuel price. Charging high fuel price raise the cost of vehicle trips and thus increase the attractiveness of alternative modes, including transit, ridesharing and non-motorized options. In addition, the revenue can be used for the improvement and investment of different public transport systems.

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# ANNEX I

## PARAMETERS FOR ENERGY PLANNING IN CHAPTER 4

- **Table A:** Road Vehicles Categories according to German-Swiss Emissions Model
- **Table B:** Average Speeds Characterization according to German-Swiss Emissions Model
- **Table C:** The Potential Reduction in Energy Intensity through the incorporation of some Technologies
- **Table D:** Average Specific Energy Consumption (Wh/km) and Emission Factors (g/km) for different Vehicles Types
- **Table E:** Average Specific Energy Consumption (Mj/km) and Emission Factors (g/km) for Different Alternatives Fuels
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- **Table G:** Expected Train Weight per Seat (t/seat)

**Table A: Road Vehicles Categories according to German-Swiss Emissions Model**

<table>
<tr><th>Vehicle Class / Fuel Type</th><th colspan="30">Size/Type</th></tr>
<tr><th rowspan="2">Passenger Cars – Gasoline</th><th colspan="10">< 1.41 L</th><th colspan="10">1.41 – 2.01 L</th><th colspan="10">> 2.01 L</th></tr>
<tr><td colspan="10">Pre-regulation<br>Pre ECE (until 1971)<br>ECE 15/00 (1972-77)<br>ECE 15/01-02 (1978-80)<br>ECE 15/03 (1981-84)<br>ECE 15/04 (1985-92)<br>Improve Convential. (1986-91)<br>One Loop (1986-91)<br>Euro 1 (1991-95)<br>Euro 2 (Since 1996)<br>Euro 3 (Since 2001)<br>Euro 4 (Since 2006)</td><td colspan="10">Pre-regulation<br>Pre ECE (until 1971)<br>ECE 15/00 (1972-77)<br>ECE 15/01-02 (1978-80)<br>ECE 15/03 (1981-84)<br>ECE 15/04 (1985-92)<br>Improve Convential. (1986-91)<br>One Loop (1986-91)<br>Euro 1 (1991-95)<br>Euro 2 (Since 1996)<br>Euro 3 (Since 2001)<br>Euro 4 (Since 2006)</td><td colspan="10">Pre-regulation<br>Pre ECE (until 1971)<br>ECE 15/00 (1972-77)<br>ECE 15/01-02 (1978-80)<br>ECE 15/03 (1981-84)<br>ECE 15/04 (1985-92)<br>Improve Convential. (1986-91)<br>One Loop (1986-91)<br>Euro 1 (1991-95)<br>Euro 2 (Since 1996)<br>Euro 3 (Since 2001)<br>Euro 4 (Since 2006)</td></tr>
<tr><th rowspan="2">Passenger Cars – Diesel</th><th colspan="15">< 2.01</th><th colspan="15">> 2.01</th></tr>
<tr><td colspan="15">Convential pre 1986<br>Convential 1986 – 1988<br>Euro 1 1988 - 1996<br>Euro 2 Since 1997<br>Euro 3 Since 2001<br>Euro 4 Since 2006</td><td colspan="15">Convential pre 1986<br>Convential 1986 – 1988<br>Euro 1 1988 - 1996<br>Euro 2 Since 1997<br>Euro 3 Since 2001<br>Euro 4 Since 2006</td></tr>
<tr><th rowspan="2">Light Duty Vehicles – Gasoline</th><th colspan="30">All</th></tr>
<tr><td colspan="30">Convential pre 1986<br>Convential after 1986<br>Euro 1 Since 1995<br>Euro 2 Since 1997<br>Euro 3 Since 2001<br>Euro 4 Since 2006</td></tr>
<tr><th rowspan="2">Light Duty Vehicles – Diesel</th><th colspan="30">All</th></tr>
<tr><td colspan="30">Convential pre 1986<br>Convential after 1986<br>Euro 1 Since 1995<br>Euro 2 Since 1997<br>Euro 3 Since 2001<br>Euro 4 Since 2006</td></tr>
<tr><th rowspan="2">Heavy duty Vehicles – Diesel</th><td colspan="6">Lorries (Solo)</td><td colspan="6">Road Trains (LZ)</td><td colspan="6">Articulated (SZ)</td><td colspan="6">Buses</td><td colspan="6">Coaches (RB)</td></tr>
<tr><td colspan="6">< 7.5 t<br>7.5 – 14 t<br>14 – 20 t<br>20 – 28 t</td><td colspan="6">< 20 t<br>20 – 28 t<br>28 – 32 t<br>28 – 32 t</td><td colspan="6">< 32 t<br>> 32 t</td><td colspan="6">< 16 t Intercity<br>> 16 t Intercity<br>< 20 t Urban<br>> 20 t Urban</td><td colspan="6">< 32 t<br>> 32 t</td></tr>
</table>

Source: [21]

**Table B: Average Speeds Characterization according to German-Swiss Emissions Model**

| Situation | Average Speed | | Classification |
|---|---|---|---|
| **Urban / Rural** | STGO IO | (V = 5.30 km/h) | (Stop and Go) Traffic Jam |
| | FM1 | (V = 18.6 km/h) | Residential Areas |
| | FM2 | (V = 19.8 km/h) | Heavy traffic, uncoordinated traffic lights, very complicated driving conditions, city center |
| | FM3 | (V = 32.0 km/h) | Heavy traffic, right of way, very complicated driving conditions, co-ordinate traffic lights |
| | FM4 | (V = 37.5 km/h) | Through city with bottle necks |
| | FM5 | (V = 46.2 km/h) | Heavy Traffic, right of way, lightly built-up, traffic lights phased at 50 km/h |
| | FM7 | (V = 58.4 km/h) | Narrow roads, heavy traffic, traffic lights phased at 50 km/h, uncomplicated driving through cities |
| | FM8 | (V = 78.3 km/h) | Steady with acceleration delays (e.g. exits from town) |
| | FM9 | (V = 72.0 km/h) | Steady with delays (e.g. driving into town) |
| | FM10 | (V = 76.7 km/h) | Steady, schedule free |
| **Highways** | v075 | (V = 70 – 80 km/h) | Highways |
| | v085 | (V = 80 – 90 km/h) | Highways |
| | v095 | (V = 90 – 100 km/h) | Highways |
| | v105 | (V = 100 – 110 km/h) | Highways |
| | v115 | (V = 110 – 120 km/h) | Highways |
| | v125 | (V = 120 – 130 km/h) | Highways |
| | v135 | (V = 130 – 140 km/h) | Highways |
| | v135 | (V = 140 – 150 km/h) | Highways |
| | STGO IO | (V = 5.30 km/h) | (Stop and Go) Traffic Jam |
| **Uphill / Downhill** | LG1 | (V = 60.9 km/h) | Continuously slope to narrowly |
| | LG2 | (V = 51.2 km/h) | Narrowly slope to non-continuously |
| | LG3 | (V = 49.9 km/h) | Non-continuous slope |
| | LS1 | (V = 59.8 km/h) | Continuously slope to narrowly |
| | LS2 | (V = 49.2 km/h) | Narrowly slope to non-continuously |
| | LS3 | (V = 46.2 km/h) | Non-continuous slope |

Source: [21]

**Table C: The Potential Reduction in Energy Intensity through the incorporation of some Technologies**

| Technology | Reduction in Energy Intensity |
|---|---|
| **Improved Transmission** | 1 % |
| **Low Resistance Tyres** | 3 % |
| **Reduced Weight** | 4 % |
| **Exhaust gas Recirculation** | 5 % |
| **Aerodynamic Improvement** | 13 % |
| **Engine Friction Improvement** | 15 % |

Source: [54]

**Table D: Average Specific Energy Consumption (Wh/km) and Emission Factors (g/km) for different Vehicles Types**

| | Electric Vehicle | | Gasoline Hybrid Electric Vehicle | Methanol Fuel Cell Vehicles | |
|---|---|---|---|---|---|
| **Speed Range** | **20 – 50 Km/h** | **50 – 100 km/h** | **20 – 100 Km/h** | **20 – 50 Km/h** | **50 – 100 km/h** |
| **SEC** | 266 | 189 | 436.5 | 471 | 334 |
| **$CO_2$** | 122 ± 55 | 94 ± 39 | 126 ± 34 | 150 ± 17 | 140 ± 10 |
| **CO** | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.17 ± 0.12 | 0.04 ± 0.02 | 0.03 ± 0.01 |
| **$NO_x$** | 0.31 ± 0.14 | 0.24 ± 0.10 | 0.09 ± 0.03 | 0.16 ± 0.07 | 0.12 ± 0.04 |
| **HC** | 0.29 ± 0.13 | 0.05 ± 0.02 | 0.13 ± 0.04 | 0.25 ± 0.11 | 0.18 ± 0.07 |
| **$SO_2$** | 0.71 ± 0.32 | 0.55 ± 0.23 | 0.36 ± 0.09 | 0.03 ± 0.01 | 0.02 ± 0.01 |

Source: [56]

**Table E: Average Specific Energy Consumption (Mj/km) and Emission Factors (g/km) for Different Alternatives Fuels**

| | Compact Natural Gas Vehicles | Liquefied Petroleum Gas Vehicles | Methanol Vehicles | Biodiesel Vehicles |
|---|---|---|---|---|
| **SEC** | 3.5315 | 3.1873 | 3.78 | 2.55 |
| **$CO_2$** | 205.1 | 217.53 | 221.88 | 160.97 |
| **CO** | 1.4475 | 1.427 | 1.8291 | 1.7147 |
| **NOx** | 0.179 | 0.0883 | 0.1324 | 0.133 |
| **$CH_4$** | 0.7974 | 0.3282 | 0.3232 | 0.197 |
| **Sox** | 0.0497 | 0.0261 | 0.0273 | 0.0547 |
| **PM10** | 0.0199 | 0.0193 | 0.0249 | 0.0249 |

Source: [57]

**Table F: Energy Consumption of a train with the resistance characteristics of the Danish IC3 used in interregional and urban traffic**

| Route | Interregional | Urban |
|---|---|---|
| **Length (Km)** | 80 | 9 |
| **Intermediate Stops** | 1 | 3 |
| **Average Speed** | 100 | 65 |
| **Steady State Energy (kJ/ton.km)** | 52.5 | 33.6 |
| **Acceleration Energy (kJ/ton.km)** | 16.3 | 139 |
| **Total energy (kJ/ton.km)** | 68.8 | 173 |
| **Relative acceleration energy (%)** | 24 | 81 |

Source: [59]

**Table G: Expected Train Weight per Seat (t/seat)**

| Type | Weight per Seat |
|---|---|
| **High Speed** | 0.4 |
| **Inter City** | 0.3 |
| **Regional** | 0.3 |
| **Urban** | 0.2 |

Source: [60]

# ANNEX II

## EXAPMLE FOR THE INPUT AND OUTPUT DATA FROM THE TraEnergy PROGRAM

- **Figure A:** Input Data Sheet for TraEnergy Program
- **Figure B:** Output Data Sheet for TraEnergy Program

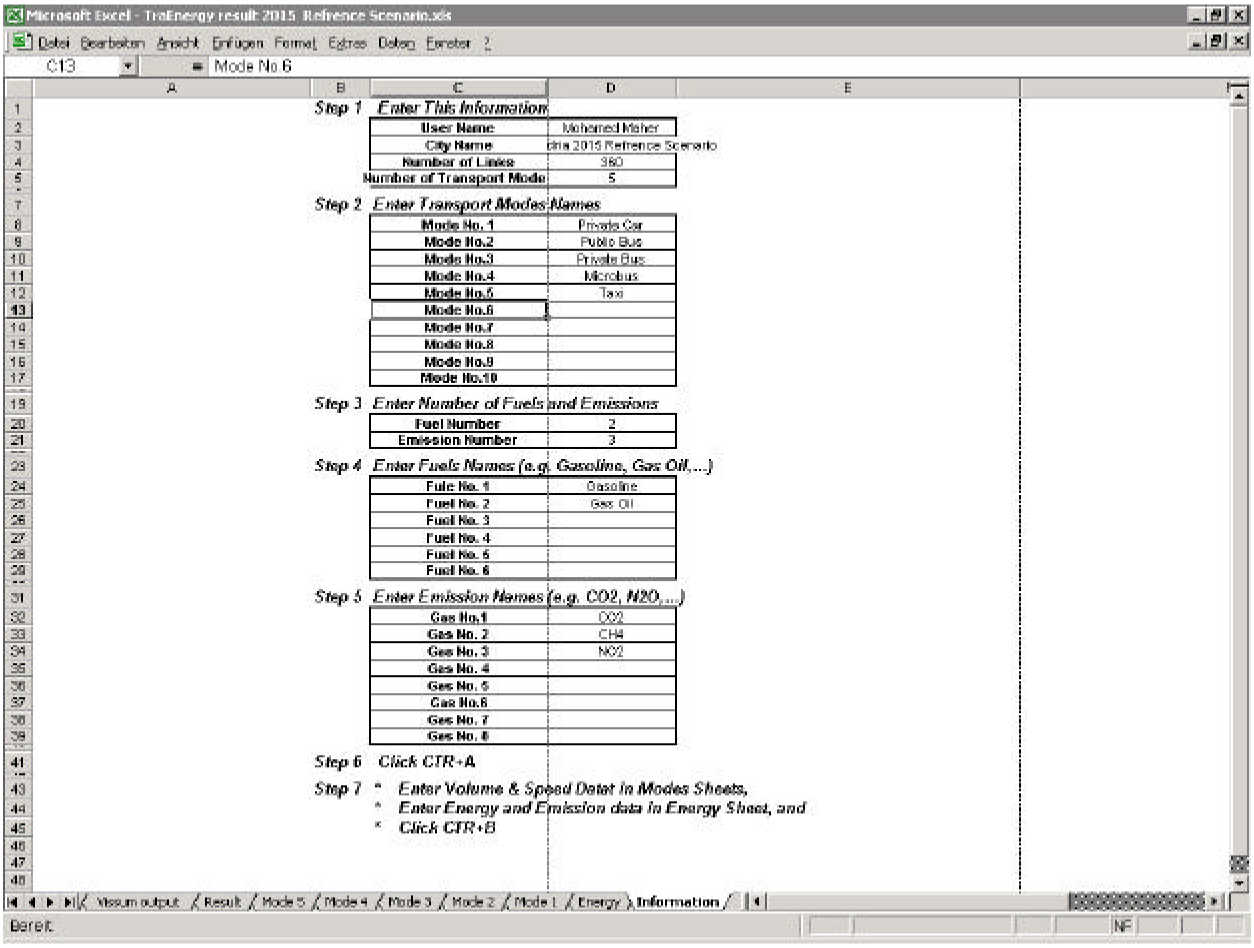
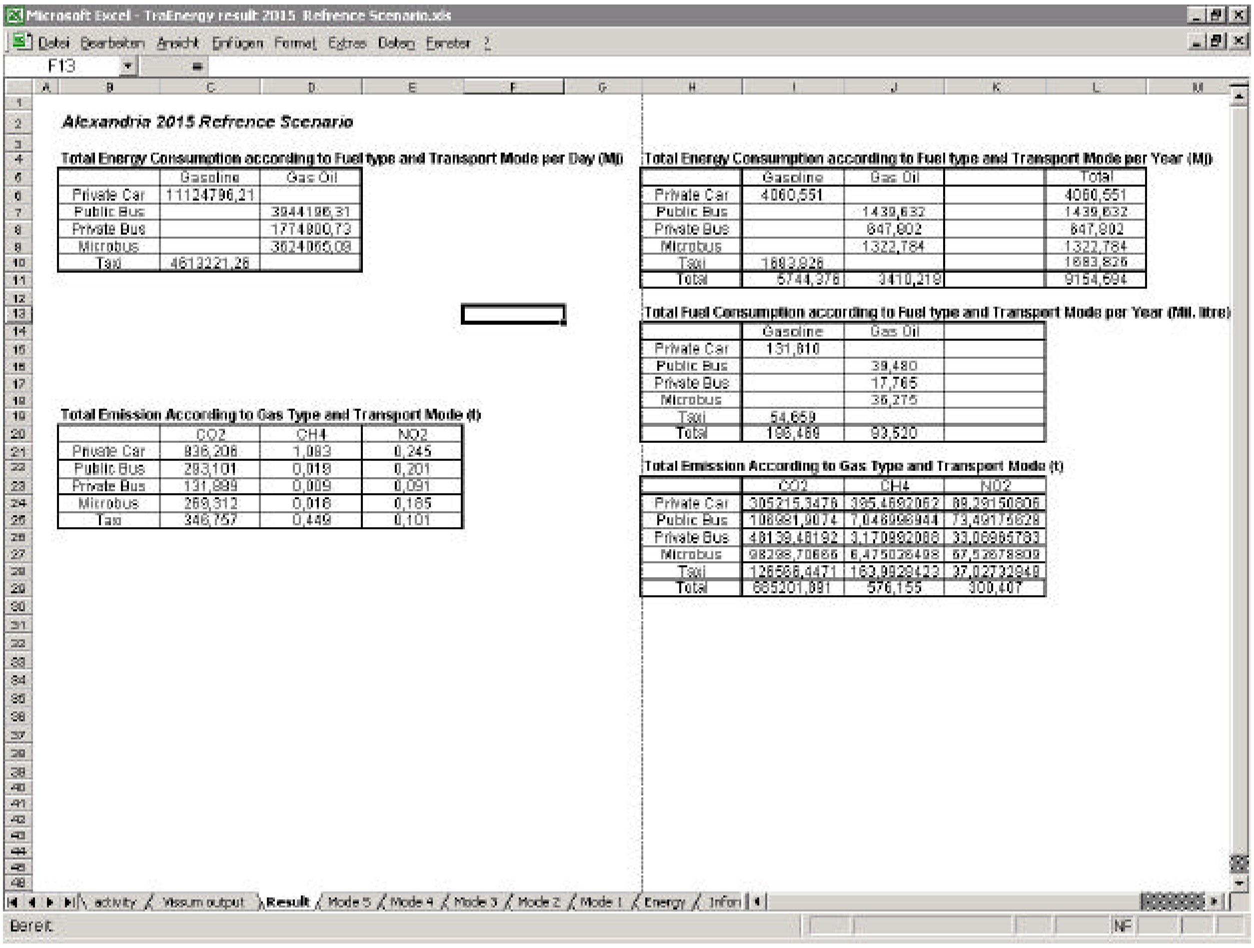



**Figure A: Input Data Sheet for TraEnergy Program**





**Alexandria 2015 Refrence Scenario**

**Total Energy Consumption according to Fuel type and Transport Mode per Day (MJ)**

| | Gasoline | Gas Oil |
|---|---|---|
| Private Car | 11124796,21 | |
| Public Bus | | 3944196,31 |
| Private Bus | | 1774800,73 |
| Microbus | | 3624065,09 |
| Taxi | 4613221,26 | |

**Total Emission According to Gas Type and Transport Mode (t)**

| | CO2 | CH4 | NO2 |
|---|---|---|---|
| Private Car | 836,206 | 1,083 | 0,245 |
| Public Bus | 283,101 | 0,019 | 0,201 |
| Private Bus | 131,899 | 0,009 | 0,091 |
| Microbus | 269,312 | 0,018 | 0,185 |
| Taxi | 346,757 | 0,449 | 0,101 |

**Total Energy Consumption according to Fuel type and Transport Mode per Year (MJ)**

| | Gasoline | Gas Oil | | Total |
|---|---|---|---|---|
| Private Car | 4060,551 | | | 4060,551 |
| Public Bus | | 1439,632 | | 1439,632 |
| Private Bus | | 647,802 | | 647,802 |
| Microbus | | 1322,784 | | 1322,784 |
| Taxi | 1683,826 | | | 1683,826 |
| Total | 5744,376 | 3410,219 | | 9154,594 |

**Total Fuel Consumption according to Fuel type and Transport Mode per Year (Mil. litre)**

| | Gasoline | Gas Oil | |
|---|---|---|---|
| Private Car | 131,810 | | |
| Public Bus | | 39,480 | |
| Private Bus | | 17,765 | |
| Microbus | | 36,275 | |
| Taxi | 54,659 | | |
| Total | 186,469 | 93,520 | |

**Total Emission According to Gas Type and Transport Mode (t)**

| | CO2 | CH4 | NO2 |
|---|---|---|---|
| Private Car | 305215,3476 | 395,4692062 | 89,29150806 |
| Public Bus | 106981,9074 | 7,046996944 | 73,49175628 |
| Private Bus | 48139,48192 | 3,170992088 | 33,06965783 |
| Microbus | 98298,70666 | 6,475026498 | 67,52678809 |
| Taxi | 126566,4471 | 163,9929423 | 37,02732949 |
| Total | 685201,891 | 576,155 | 300,407 |

**Figure B: Output Data Sheet for TraEnergy Program**

# ANNEX III

## THE OUTPUT DATA AND GRAPHICS FROM DYNAMIS PROGRAM FOR THE ABOU-KIR RAILWAY LINE

- **Figure A:** Abou-Kir Line from Alexandria Station to Abou-Kir Station
- **Figure B:** Abou-Kir Line from Abou-Kir Station to Alexandria Station
- **Figure C:** Proposed Regional-Urban Line from Amria Station to Abou-Kir Station
- **Figure D:** Proposed Regional-Urban Line from Abou-Kir Station to Amria Station

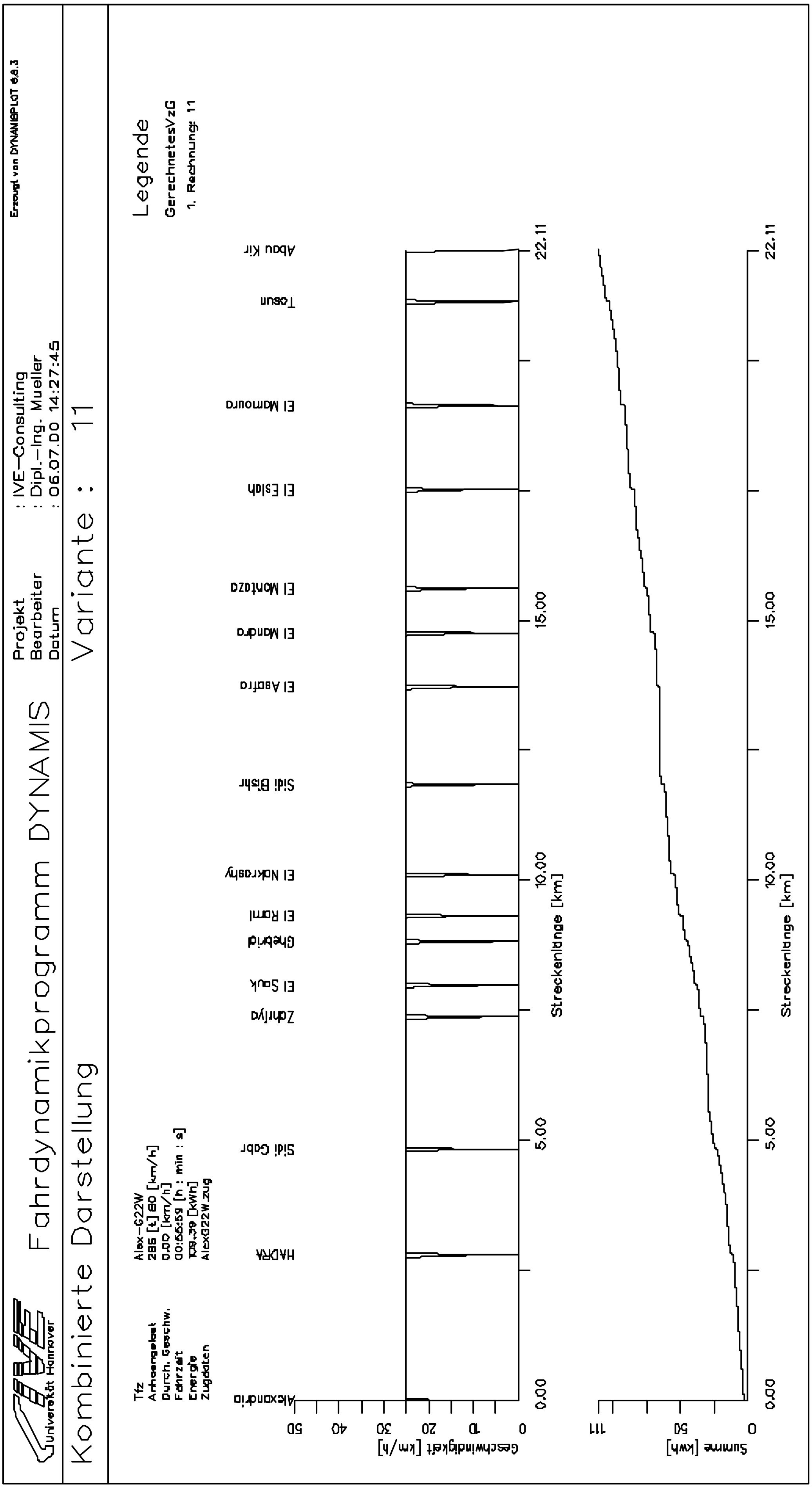



**Figure A: Abou-Kir Line from Alexandria Station to Abou-Kir Station**

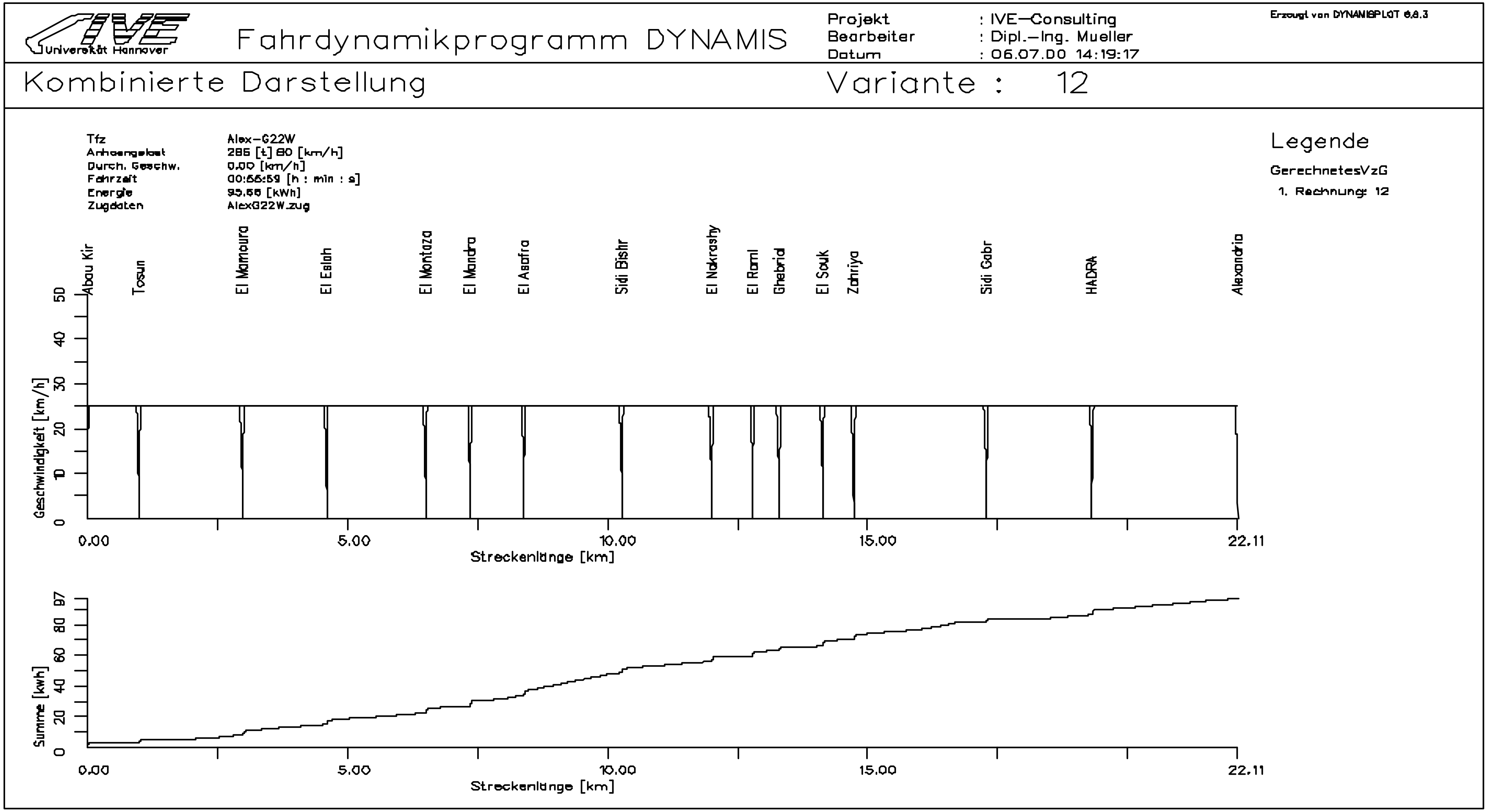



**Figure B: Abou-Kir Line from Abou-Kir Station to Alexandria Station**

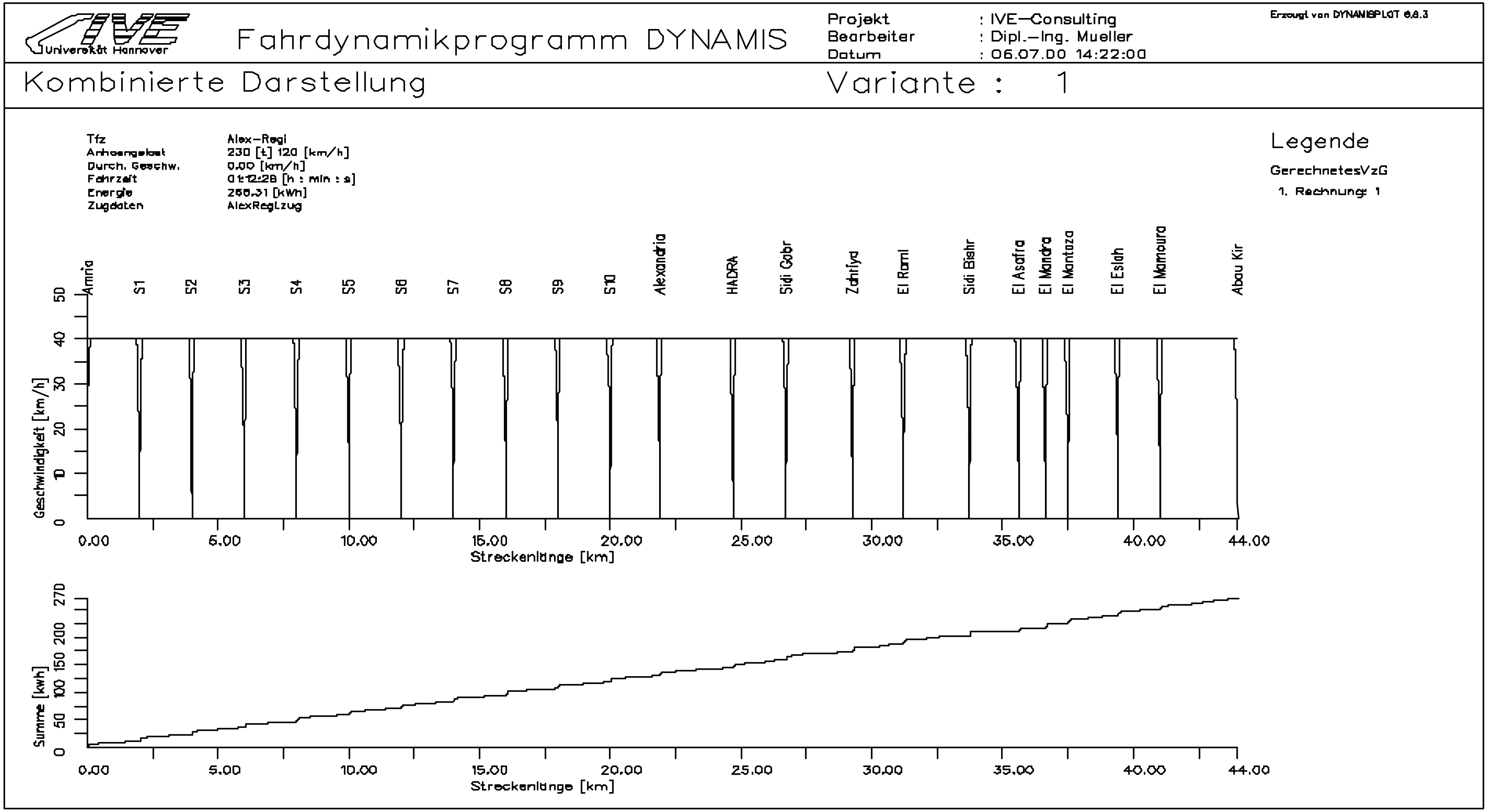



**Figure C: Proposed Regional-Urban Line from Amria Station to Abou-Kir Station**

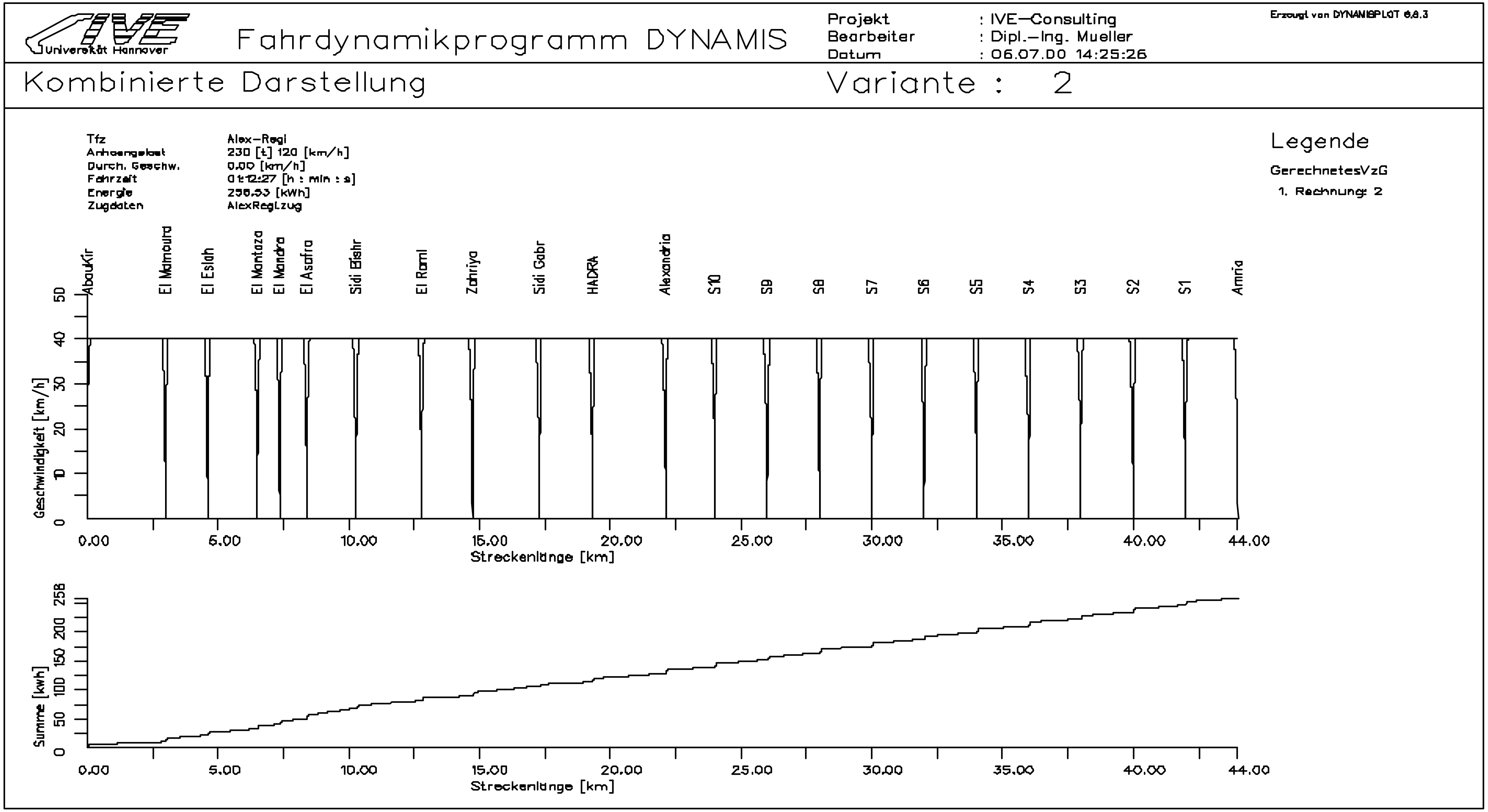



**Figure D: Proposed Regional-Urban Line from Abou-Kir Station to Amria Station**